PHOTOGRAPHY APPLIED TO SURVEYING

LIEUT. HENRY A. REED, U.S.A.

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BY

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PREFACE.

IT would seem from the scarcity of published information on the subject of this treatise, that its practical value has not been justly appreciated. In foreign countries, and particularly in France, photography has been for a considerable period applied to surveying; and the results show a saving of time and labor that cannot be attained by any other known means; and, as in ordinary surveying, an accuracy that is directly proportioned to the quality of the instruments employed and to the care exercised in the field-work. In the United States, photographs are sometimes used as addenda to an important map, because they are recognized as conveying information to be otherwise gained only by actual inspection of the tract or subject represented; and when it is considered that in themselves they present all the data necessary for the construction of a map, thus rendering field-work other than that required for their production unnecessary, then certainly this method needs but to be better known to be appreciated.

In his own practice its value is so strongly impressed, that the author feels it a duty to try and present the subject in a plain and concise manner, trusting that others may so improve and enlarge upon it, that this method of surveying will not fail to become more generally understood and practised.

Of the numerous foreign authors whose recent works have been referred to for information may be mentioned Laussedat, Girard, Gossin, Hannot, Bornecque, Javary, Tissandier, Dufaux, Pizzighelli, Keucker and Colson. Acknowledgment is also due for information obtained from the periodicals *La Revue d'Artillerie*, *La Nature*, and the *Bulletin de la Société Française de Photographie*.

WEST POINT, N. Y., January 23, 1888.

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PHOTOGRAPHY APPLIED TO SURVEYING.

SECTION I.

INTRODUCTORY.—HISTORICAL SKETCH AND GENERAL PRINCIPLES.

HISTORICAL SKETCH.

1. PERSPECTIVE drawings were used as data for the construction of plans long before the practical application of photography. Near the beginning of the present century, Beautemps-Beaupré called attention to their use in topographical surveying. The instructions prepared by him for the officers of the frigate Bonite, preceding a voyage around the earth, recommended them for the survey of the surroundings of places visited, and of the coasts which were either passed by or could not be reached. His method was simply to make drawings or careful sketches of the subject from any two stations, of which the distance apart was determined; then, by measuring with a sextant or other means, at each station, the angle included by a visual ray to any point and the right line joining the stations, data were afforded for orienting the sketches on the plot; and a simple geometrical construction, the reverse problem of perspective drawing, then sufficed to locate the details in plan. The accuracy of the result evidently depended upon skill in sketching. Colonel Leblanc subsequently endeavored to apply this method to military topography; but found, even under the most favorable circumstances, that the results were only approximately exact; and, having but few advocates, it was no longer employed. The result of these attempts induced Colonel Laussedat, professor of geodesy at the polytechnic school, to try ano find some means whereby ordinary skill in drawaing would suffice for the production of accurate maps; and, in 1854, his efforts ended successfully in his well-known adaptation to the purpose of Wollaston's camera lucida; and later in the telemetrograph,—a combination of the camera lucida and telescope.

In 1839, when Arago presented Daguerre's famous discovery to the French Chamber of Deputies, he said, " That the subjection of photographic images in their formation to geometrical rules will enable us with very few data to determine from these images the exact dimensions of the highest objects, of the most inaccessible structures. . . . We could give some ideas we have entertained of rapid means of investigation that the topographer will be enabled to borrow from photography. . . ."

In 1847, Martens, a French engraver, constructed a panoramic apparatus consisting of a camera with a cylindrical daguerreotype plate vertically disposed; the plate remained stationary, while the part containing the objective revolved; the light acted upon the plate through a small vertical slit in a diaphragm placed opposite the objective. Sharply-

defined images were thus produced; but the preparation of the curved plate, and sensitizing it by the collodion process, were attended with too much difficulty to make the apparatus useful.

Martens' instrument was modified by Garella, L. Schuller, and also by Brandon, so that the image was received upon a flat plate. The camera, by means of clock-work, was made to revolve about a vertical axis through the optic centre of the objective, carrying with it, and in rear of the objective, a screen which contained a vertical slit; a narrow sector of light was thus admitted; at the same time the plate was made to move and occupy positions such as to be continuously tangent to the cylinder described by the base of the sector. Vertical lines were faithfully represented, but horizontals, not contained in the horizon of the instrument, were represented by curves.

Similar modifications were made by J. Martens and by Koch; and Silvy substituted for the glass and metal plates a sensitized paper which was made to roll from one cylinder to another.

In 1856, M. Chevallier made his first researches in this direction, and succeeded in forming upon a single plate, horizontally disposed, an entire tour of the horizon. As the camera he employed belongs to a class having certain special merits, a detailed description of it in its present improved condition is given in the text, par. 46. Mangin's camera also belongs to this class, and its description follows that of the former instrument.

In 1858, M. Porro, a maker of instruments of precision, proposed an ingenious apparatus intended especially for topographical purposes; but the transformation of the images necessary to the construction of the plan was so tedious and complicated, that it was never brought into use.

Other modifications or improvements in panoramic cameras were made in 1857 by Ross and Brooman, in 1861 by Sutton, in 1864 by Johnson, about 1865 by Busch, and quite recently by Liesegang of Dusseldorf; these instruments receiving various names, such as the "pantoscopic camera," "metoscopic camera," and the "camera of rotation."

About 1858, M. Carette invented a camera giving views about two inches square, and insured the verticality of his plates by means of a circular level. While he made the exposures, an assistant measured with a pocket sextant the angles necessary to fix the photographic stations. The negatives were used directly to obtain the coordinates of different points of the perspective. This camera was employed simply as an accessory to the ordinary topographical instruments to fix some of the points upon the sketch.

In 1864, Colonel Laussedat, now Director of the National Conservatory of Arts and Trades in Paris, published in the *Mémorial de l'Officier du Génie* a very thorough description of photographic surveying, in fact so exhaustive that at the present date no treatise upon this subject can be complete without making use of the results of his researches, and no practice perfect without applying the principles that he established. He may be called the inventor of practical photographic surveying. Two of his most extensive undertakings were a partial survey of Paris in 1861, and of Grenoble and its suburbs in 1864, the latter in charge of Captain Javary. In each case the topographical maps were characterized by great accuracy; in the former, agreeing precisely with the regular survey made by the engineer in charge of roads and bridges, and in the latter the

differences of level as compared with the regular survey nowhere exceeding 19 inches, which for ordinary scales is of course within the limit of permissible error.

During this period, and while Col. Laussedat's method was practised in France, experiments were made in Germany by Meydenbauer, the counsellor in charge of public buildings, with a view to applying photography to land and architectural surveying. Apparently unaware of the researches of Beautemps-Beaupré and Laussedat, he first resorted to photography for the construction of plans and elevations of certain structures, difficult of access; and like that of Beautemps-Beaupré, his method consisted in determining the orthographic projection from the photograph by reversing the direct perspective problem. In land-surveying, his method was based upon the same principles as Laussedat's; but on account of the very narrow field of view which, in the objectives then employed, corresponded to a true image, he would soon have abandoned his very costly experiments had it not been for the optician Busch of Rathenow, who at this juncture invented the pantoscope. This instrument, presumably similar to the modification of Martens' heretofore described, gave a true image for a field of view of 105°; the only fault consisting in an unequal brilliancy of the centre and edges, which however could be avoided by securing a favorable illumination of the subject. (Steinheil's apparatus, now in use, is exempt from this fault.) Meydenbauer's work now began to attract much attention, and "photogrammetry," as the method with both the pantoscope and the ordinary camera was termed, was more extensively applied. One of his trial surveys was that of Fribourg and its suburbs, covering an area about half a mile square, which was plotted to a scale of $\frac{1}{1000}$, with 10 feet contours, by himself and a draughtsman who had not taken part in the field-work. The field-work required 2 days; there were 6 stations and 21 plates; the office-work was performed in 3 weeks: and the resulting map was accurate in every respect. Elevations of buildings were also obtained with like success.

During later years, several different instruments for the purpose have been invented, of which the most important appear to be Duboscq's Polyconograph, Bertsch's Automatic Camera, and Dubroni's Apparatus. In the first mentioned, the inner surface of the shield of the plate-holder was subdivided by raised strips into fifteen equal squares, and the strips being of such thickness as to touch the sensitive plate, the latter was practically subdivided in a like manner. A metal part of the camera containing the lens could be fastened at pleasure opposite any one of these squares, and an exposure made by means of a corresponding opening in the shield. The focussing was effected with the aid of a ground glass placed in the prolongation of the sensitive plate, the lens part being attached to it for this purpose. This instrument was of very small dimensions, the tripods when folded serving as a cane.

The term "automatic" was applied to Bertsch's camera because it was focussed permanently for distant views. The camera consisted of a four-inch metal cube, a lens of four-inch focal distance, and the sensitive plates were two and one half inches square. The proper direction for any view was given by means of an alidade with attached level, having at one extremity an open rectangle which, with the other extremity of the alidade as the point of observation, exactly limited the field. The negatives produced were so sharply defined as to admit of a useful enlargement of from 100 to 500 times their super-

ficial area. A field laboratory, contained in a box fifteen inches square, accompanied the camera.

The main features of Dubroni's Apparatus were its easy manipulation, and the use of the camera itself for developing the plates. The camera was a box with yellow glass sides, enclosed in another box of wood; openings were provided as usual for the lens and for introducing the plate. The latter having been collodionized and introduced, the box was inverted, lens upward, and the silver solution was poured in through a tube. The plate being thus sensitized, the instrument was then pointed and the exposure made; the box was again inverted and the plate developed by introducing the required solution; the fixing was delayed till the day's survey was finished. Since the focal distance was adjusted by the instrument-maker, and rules for the manipulation accompanied each instrument, the work could be performed by those not at all skilled in photography.

Doubtless other important inventions of this nature exist; but those mentioned give an idea of the progress made in the past, and, together with the instruments described in the text, will serve to give a fair knowledge of the development of this very important aid to surveying.

GENERAL PRINCIPLES.

2. *Range and Object of the Method.*—Although the range of Photographic Surveying extends to geodetic measurements, it is limited in the present treatise to ordinary plane and topographical work.

As in surveying with compass or transit, this method has for its object the measurement of angles and distances necessary to the location of points, for a graphical representation of the important features of a limited portion of the earth's surface. Like an ordinary topographical map this representation is a horizontal projection with added references for heights; but beyond this, the means employed furnishes, without additional labor, a complete view of the tract surveyed, with its details as they would be naturally presented to the eye, which

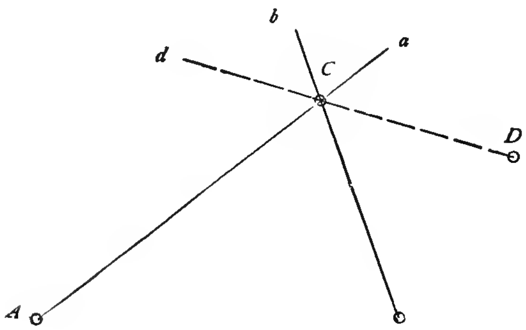

FIG. 1.

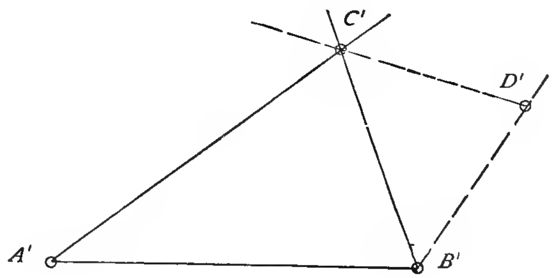

FIG. 2.

addition evidently increases the value of the result. Its accuracy, as will hereafter be shown, may be said to be sufficient for the purposes above stated.

3. *Location of Points.*—Two ways of locating points are used.

I. By the intersection of two or more right lines through given points;—thus, C (Fig. 1) is fixed in position if, from two given points, A and B, the directions Aa and Bb are known; and if from a third point, D, Dd is also given, and Dd intersects C, a

check upon the work is afforded. It is evident that curved lines serve the same purpose if their positions are known.

C may also be fixed if, as shown in Fig. 2, the distance $A'B'$ and the angles $C'A'B'$ and $C'B'A'$ are given; and, as before, a third point D', being fixed, and the angle $C'D'B'$ given, a check is also afforded.

II. By an Azimuth and a Distance.—Thus, in Fig. 3, the point E, of the right line EF, given; G is fixed, if the azimuth z and the distance EG are known. A check is had either by another azimuth and distance, or by the application of (I), using other known points and lines.

The foregoing constructions apply to plane-photographic surveying. To locate a point completely requires that not only shall its position in plan, or its projection upon a horizontal plane, be determined; but also that its elevation or depression with reference to this plane shall be known. Thus, in Fig. 4, let K be the required point; its projection k in plan may be found by (I) or (II), *e.g.*, as indicated, by the azimuth z and distance Hk; but its complete determination requires the elevation or distance h above this plane. This is ordinarily found in photographic surveying, by measuring the angle of elevation

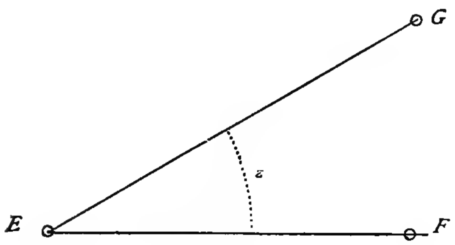

FIG. 3.

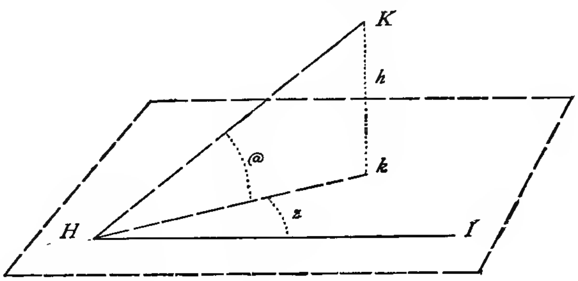

FIG. 4.

@ by means hereinafter explained; then $h = Hk$ tang. @. The position of a point below the horizontal plane is similarly determined by measuring the angle of depression.

4. *Relation of Photographs to Perspective Drawings: Definitions of Terms.*—The ready application of photography to surveying requires that the photographs taken in the field shall be accurate representations of the features included in the field of view; in other words, that they shall be true perspectives. The definitions of certain terms used in perspective drawing may here be found appropriate. In Fig. 5, the picture V represents the distant topographical features as shown, and O the eye of the observer. V is called the *plane of the picture*, and, for convenience in the application of geometric rules, is taken in a vertical position; O is the *point of sight;* P, the point in which a visual ray perpendicular to V pierces it, is called the *principal point,* the horizontal line HH' through P is the *horizon of the picture*, or simply the *horizon*,—it is evidently the intersection with V of the observer's horizon; and the points in which visual rays, or right lines from distant points to O, pierce V, are the *perspectives of these points;* thus a, b, ... are the perspectives of A, B, ... These elements will be frequently designated hereafter by their distinguishing letters as above given.

5. *To Determine the Direction of a Point from a Perspective Representation.*—If the different points of a landscape and the visual rays intersecting them be vertically pro-

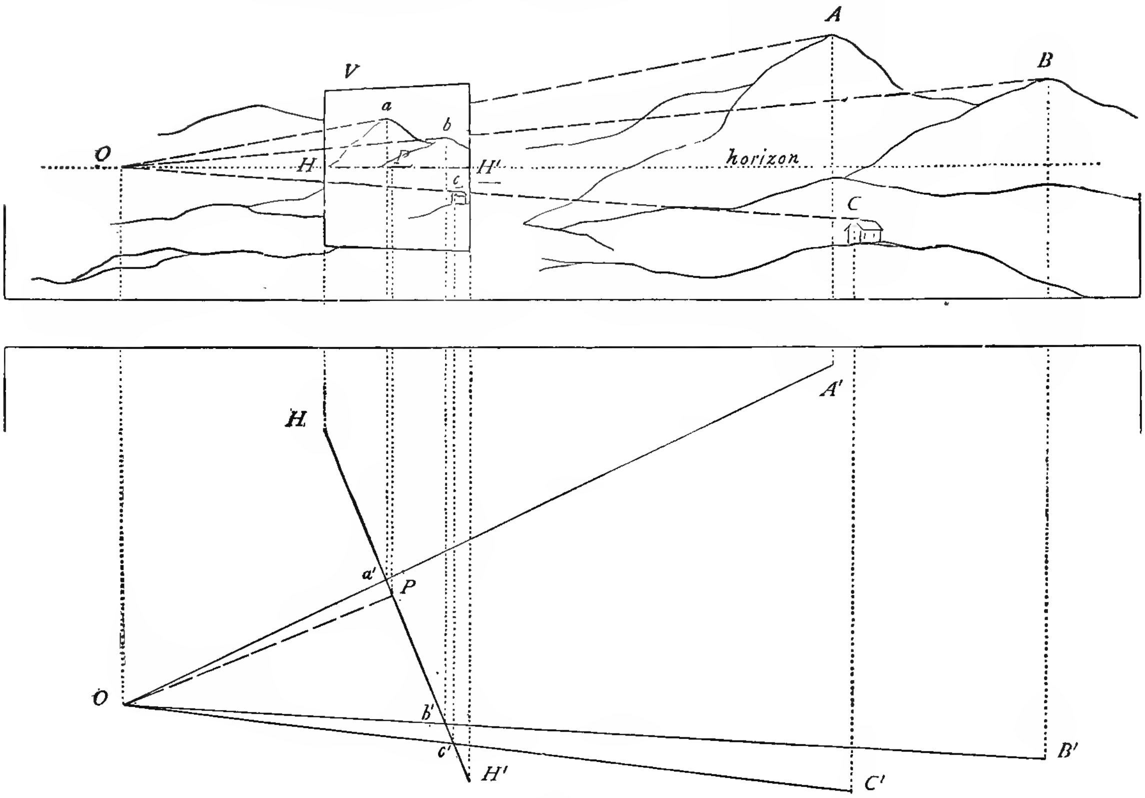

FIG. 5.

jected into the plane of the horizon, the angles included by the projections of the visual rays are the true horizontal angles; the same that would be measured with a theodolite or any other horizontal angle-measurer:—Thus, in Fig. 5, *OP* and *HH'*, since they are in this plane, are their own projections; *OA* and *OB* are horizontally projected in *OA'* and *OB'* . . . .; and *a'Ob'* is evidently the horizontal angle included by *OA'* and *OB'*; *a'Oc'* the angle included by *OA'* and *OC'* . . . . Now let *V*, Fig. 6, represent a perspective, as in Fig. 5;—Since the positions of *HH'* and *P*, and the distance *OP*, are always known; if *V* be laid upon a flat surface, *PO* can be set off perpendicularly to *HH'*, the different points *a*, *b*, ... may be projected vertically into *HH'*,—see *a'*, *b'*, ... in the figure,—and the horizontal angle between any two points will then be included by the right lines joining their projections with *O*. Thus *a'Ob'* is the true horizontal angle of the points *A* and *B*,—*a* and *b*, in the figure. Hence the direction from *O* of the projection of any point on the horizontal plane may be determined from the perspective.

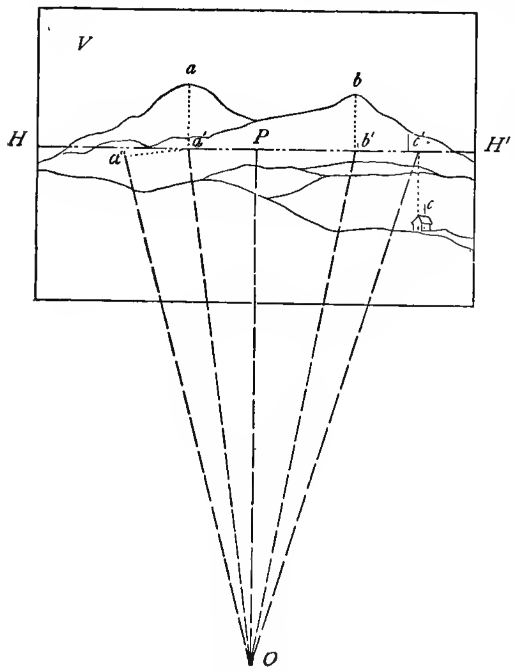

FIG. 6.

These angles may be measured with a protractor; or, since Pa', Pb' .... are the tangents, to the radius OP, of the angles which they respectively subtend, any angle may be determined by first measuring its tangent with a scale of equal parts; then the distance thus obtained, divided by OP, is the natural tangent of the angle, and the angle is given in a table of natural tangents:—Thus, tang. $a'Ob' = \frac{Pa' + Pb'}{OP}$ ...; $b'Oc'$ is obtained by determining POc' and POb' separately, then $b'Oc' = POc' - POb'$.

The vertical angles are similarly determined; e.g., to find the angle of elevation of A (a in the figure); set off $a'a''$ perpendicular to Oa' and equal to $a'a$, then measure $a''Oa'$ with a protractor; or, since $a'a''$ is the tan. $a''Oa'$ to the radius Oa', measure Oa' with a scale of equal parts, then tan. $a''Oa' = \frac{a'a''}{Oa'}$.

Therefore, since its azimuth and vertical angle (see also Fig. 4) are given, the *true direction* of any point with reference to O may be determined from a perspective representation.

6. *To Determine the Position of a Point from a Perspective Representation.*—The other

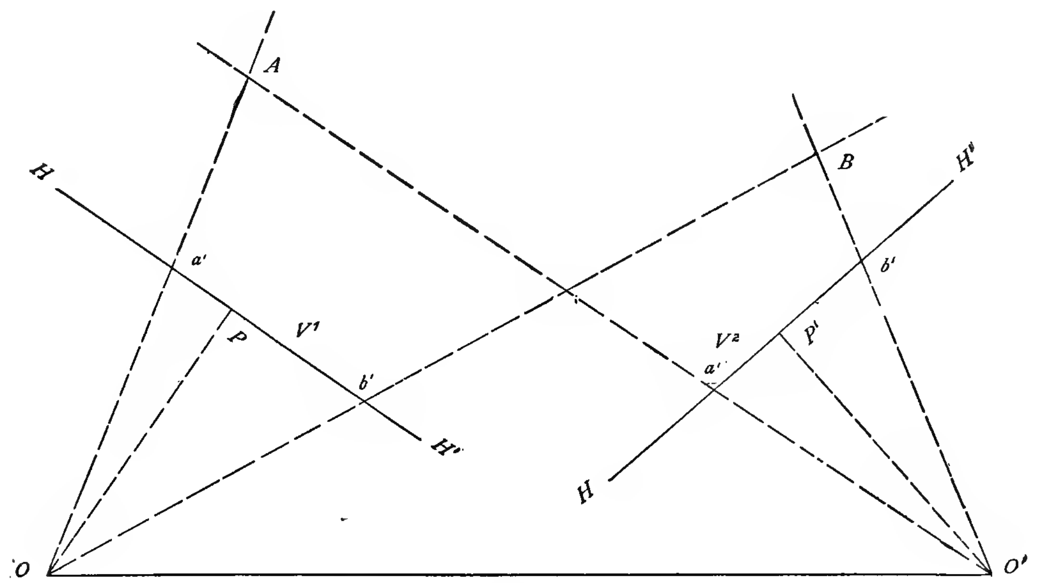

FIG. 7.

element required to fix a point completely is its distance from O, or, which is equivalent, its direction from some other point of which the position with reference to O is known. The latter method is generally used in photographic surveying; in other words, in this process, points are fixed by intersections from known points.

This method requires that the points of observation O and O', Fig. 7, of two views, V' and V^2, shall be fixed, and the directions of OP and $O'P'$ known: if the positions of the horizons HH' are then given, it is only necessary to draw right lines from O and O' through the projections of any point on these horizons and produce them to intersection:—Thus, to fix A in plan; produce Oa' till it intersects $O'a'$, and similarly for any other point represented on both views. The view from a third known point,

embracing points on the other two views, would serve to check the accuracy of the plot.

To avoid repetition, the orientation of the views, or the determination of the required directions of OP and the consequent positions of HH' for the different views, is deferred to Plotting, par. 24 *et seq.*

The remaining element to determine is the reference, or the distance of any point above or below the horizontal or datum plane. Referring to Fig. 8; the distances Oa'

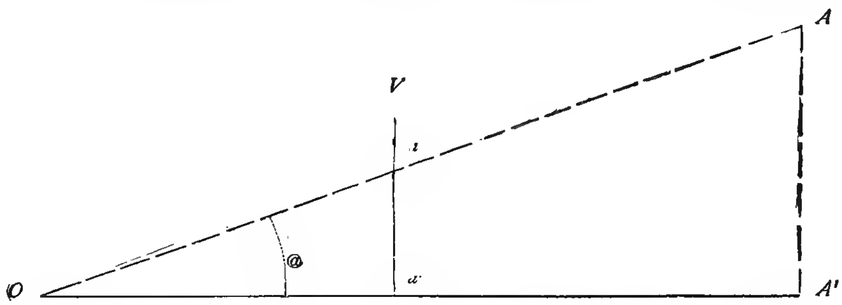

FIG. 8.

and $a'a$ being measured on the view, and OA' measured on the plot; then $Oa' : OA' :: a'a : A'A$, whence $A'A = \frac{OA' \times a'a}{Oa'}$; denoting $A'A$ by H, and OA' by D, and since $\frac{a'a}{Oa'}$ is the tang. @ (see figure) to the radius Oa', there results the general expression for the reference of a point

$$H = \pm D \text{ tang. } @\,;$$

the $+$ and $-$ signs referring respectively to distances above or below the datum plane.

Since the position of a point may thus be found, any point may be *completely determined* from a perspective representation.

The next step is to describe the instruments and means employed in the Field-work.

SECTION II.

METHOD BY PLANE PERSPECTIVES.—INSTRUMENTS AND MATERIALS, FIELD-WORK AND PLOTTING.

INSTRUMENTS AND MATERIALS.

THE instruments and material required to obtain a photographic perspective are the camera with its objective, a compass, level, certain other appliances which will be described in their appropriate places, and the sensitive plates.

7. *Camera for Plane Perspectives.*—Fig. 9 represents the kind of camera used for this purpose; it is the kind generally used for photographic work. Its principal parts are the back *B*, front *F*, bellows *b*, objective *O*, objective-slide *D*, ground-glass *G*, rails *R*, and tripod *T*. *H* is the plate-holder, *s* its shield, and *p* the needle-points, of which the use is hereinafter described. Any carefully-constructed camera of this type can be used with good results. The special requirements are that the different parts shall be so fitted to each other as to admit of rigid and uniform adjustment. The tripod legs should be quite stiff, and when of the ordinary telescopic pattern, as in the figure, the levelling of the instrument is very quickly effected; the binding screw which secures the camera to the tripod-head should be large and strong. In focussing with the special pattern shown in the figure, the back is fixed to the rails, while the front is made to traverse by means of the milled head shown at the base of the front; but the ordinary pattern, in which the back is made to traverse, evidently serves the same purpose.

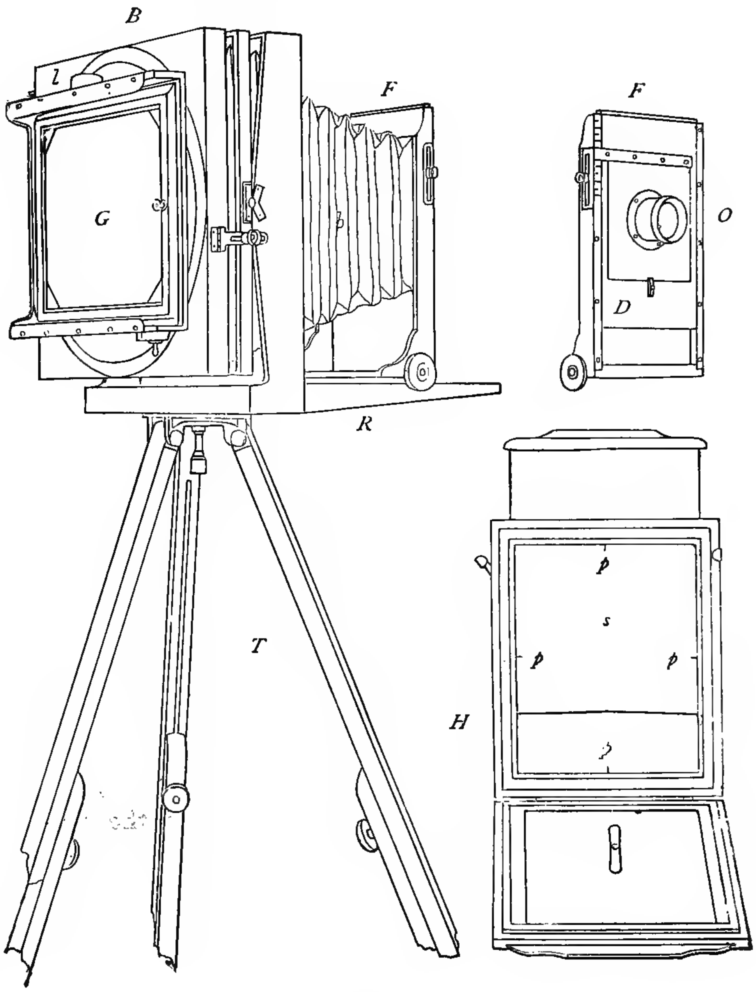

FIG 9.

When adjusted for taking a view for surveying purposes, the optic axis of the objective should be horizontal, and the film surface of the sensitive plate—the plane of the picture (par. 4)—perpendicular to it. This condition is generally assured by levelling the camera when the ground-glass and objective-slide are parallel; and it also requires that the plate-holder should so fit the back, that the sensitive plate when inserted shall exactly replace the ground-glass. In a well-constructed camera these conditions either exist permanently, or are capable of adjustment as will be hereinafter explained. The form shown in Fig. 9 is called a "double swing-back," because the back can be turned a few degrees about either a horizontal or a vertical axis, and the plate may thus be placed and clamped in positions oblique to the optic axis; this appliance is very convenient for ordinary photographic work, but unnecessary for the present purpose; in fact, with a swing-back, an additional adjustment is required to make the ground-glass and objective-slide parallel; a plain, rectangular, bellows camera, firmly constructed, is the simplest and best for surveying purposes. (See also close of pars. 20 and 24.)

8. *The Objective.*—An objective is required that will produce upon a plane surface a true perspective of a landscape, or at least one sufficiently exact for the present purpose. There are doubtless other suitable forms, but those known to the author are Dallmeyer's Rapid Rectilinear, his Wide-angle Rectilinear, Steinheil's Aplanatic, and the Hermagis 90° Angle objectives; they are respectively English, German, and French patterns adapted to surveying purposes; and the accuracy of representation resulting from their use is directly proportioned to the care exercised in the field- and office-work. Each consists of a double combination of lenses; each combination being made by joining a concavo-convex lens, *a*, Fig. 10, of which the concave face has the greater curvature, and a meniscus, *b*, Fig. 10, of which the convex face has the greater curvature. In the Dallmeyer combinations, the former is of flint, and the latter of crown-glass; while in the Steinheil they are of flint-glass, but of different density.

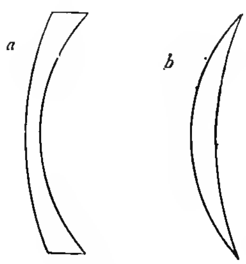

FIG. 10.

Fig. 11 shows the manner in which the lenses are arranged in the objective-tube, thus forming a symmetrical double combination. By this construction and the use of proper diaphragms, or "stops," one of which, *s*, is shown inserted, these objectives are corrected for spherical and chromatic aberration and are free from distortion; therefore by accurately focussing, the images formed are true and distinct throughout.

Fig. 12 represents the Rapid Rectilinear 10×12, the greater number indicating in inches a side of the largest square plate which may be effectively covered by the image: the dimensions 10×12 are the trade size of the plate. The lens-tube *T* is attached by means of a screw-thread to the flange *F*, which is fastened by screws to the objective-slide; the cover or cap fitting the extremity *E* of the tube, and used in making ordinary exposures, is usually of leather lined with velvet; it should fit closely, and at the same time permit of removal without jarring the camera,—a pneumatic shutter, adjustable for either time or instantaneous exposures, is much to be preferred.

9. *Compass and Level.*—A convenient form of an attached *compass* is that in which the degree graduations are numbered from 0° to 360°, from right to left, or in the inverse order of the numbers on a watch-dial, and the 0°–180° line is in the vertical

plane of the optic axis of the objective, or in a plane parallel to it, the 0° being to the front; for in this case, when the camera is pointed toward the N.E. quadrant, the indications will be in the natural order from 0° to 90°, and so on throughout a revolution, thus requiring no computation, and that the numbers only of the graduation be recorded.

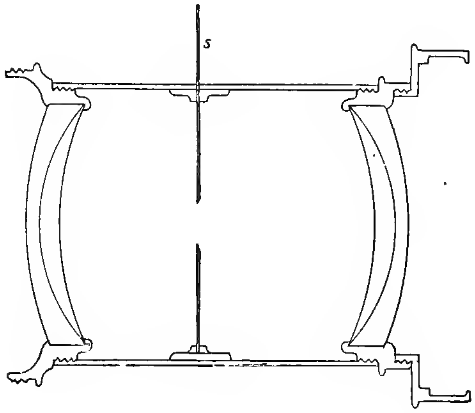

FIG. 11.

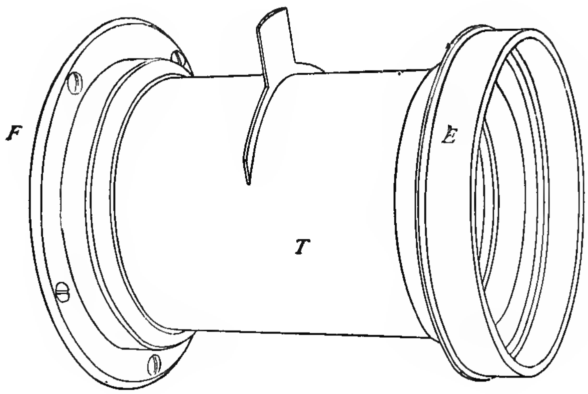

FIG. 12.

In the absence of an attached compass, a hand-compass will serve the purpose, and for convenience while reading may be rested upon the top or on the rails of the camera.

The *level* may be fixed to the camera by the instrument-maker or detached, and in either case the circular form, Fig. 13, is very convenient. If attached, it is desirable to have two of this form, one on the back and the other on the front of the camera: one is shown in position at *l*, Fig. 9.

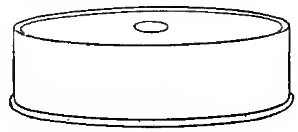

FIG. 13.

10. *Sensitive Plates and Changing-boxes.*—During most of the period considered in par. 1, rapid dry plates were unknown, consequently the work was obstructed by cumbersome apparatus and the delay incident to long exposures and field development. At the present time, not only have dry plates been brought to a state of great perfection; but, where very light outfits and great rapidity of manipulation (as instanced in the roller plate-holder) are elements of prime importance, paper has replaced glass. It is well to state, however, in this connection, that for exact work in surveying, glass negatives have not yet been equalled; they retain their shape, and the images are thus undistorted by chemical manipulation;—(see also par. 32.)

Any of the standard dry plates are suitable; but with reference to detailed representation, a 5×8 (inches) is the smallest that can be used to advantage. They are taken into the field in their original packing-boxes,—the plate-holders, of which six double ones are a convenient number, having first been filled in the dark-room. A negative-box for exposed plates is necessary; also a "field-tent," or a thick orange or ruby-colored cloth, underneath which the plates may be transferred as needed from the plate-holders to the negative-box, and from the packages to the plate-holders. A changing-box is also used for this purpose; the plates sliding directly from it to the holder, and the converse, making the tent or cloth unnecessary.

A recent invention, due to Capt. de Torres of the Spanish army, consists of a wooden box of sufficient dimensions to contain 24 plates, which are held parallel and at a small distance apart by lateral grooves. One of its sides, double the length of the box, slides in longitudinal grooves and contains a central vertical slit, large enough to permit a plate to pass freely through it; and an indexed scale and button on one of the edges serve to place and fasten the slit opposite any plate. A corresponding slit is in one extremity of the plate-holder, and each slit is furnished with a stiff cloth screen which opens and closes automatically. To transfer a plate: the end of the plate-holder is placed against the side of the box, so that the slits are opposite each other; the box is tilted, and the plate slides into the holder, where it rests upon four small triangular pieces of steel placed midway of the sides of the latter, and which also serve the same purpose as the needle-points (par. 7): the plate is held firmly in place by a clamp-screw of which the milled head projects at the back of the holder. As an additional safeguard against the admission of light during the transfer, the end of the holder is made to fit grooves on either side of the slit in the box. A plate after exposure is transferred back in a similar manner.

Another and very simple device consists in making the camera-back of metal and of sufficient size to contain, say, a dozen plates, each plate contained in the thin flexible holder which is in common use. The plates in place, a leaf-spring attached to the rear inner face of the box or back, and which bends downward, forces the plates to the front. The cover of the box consists, in addition to the lid, which is closed for transportation, of a rubber cloth, large enough to admit of the shield being withdrawn within it from any holder, and also to permit a holder, after exposure of its contained plate, to be transferred from the front to the rear of the series. The last plate-holder of the series is readily distinguished by a notch cut in its shield.

11. *Tests and Measurements Required.*—It has been observed that for good work the different parts of a camera should be susceptible of rigid and uniform adjustment; appliances are also needed in the field operation of levelling, to determine the horizon of a view; certain preliminary tests and measurements are therefore necessary, and these taken in their appropriate order are:

I. The Test for Register.

II. The Measurement of OP, or the Focal Distance.

III. The Determination of HH' for any View.

IV. The Measurement of the Field of View.

To these is added a Test for Distortion.

Since the accuracy attained in field-work and plotting will depend almost entirely upon the result of these operations, hardly too much care can be exercised in their performance.

12. *Test for Register.*—When the plate-holder is inserted, the camera should "register;" that is to say, the film surface of the sensitive plate should exactly replace the rough surface of the ground-glass. To test for this: focus an object, a few yards distant, accurately on the latter, using a large stop; then substitute for the sensitive plate a plate of ground-glass, or of other glass covered with a thin translucent film, the film to the front; withdraw the shield and observe if the image is as distinct as before; if not,

note and mark on the rails the distance the back has to be moved to the front or rear, to make it so, and adjust accordingly in making exposures. As in cases of other faults of construction, when this test is made at first and the defect discovered, the instrument-maker should remedy it.

13. *Measurement of the Focal Distance, or OP.*—For general work in photography, the focal distance of an objective, the distance of the focus from the optic centre, is variable, depending upon the distance of the subject from the optic centre; but, in surveying, since the nearest points of the features to be represented are usually so far distant that the rays of an incident pencil from any point may be regarded as parallel, the focal distance for parallel rays is required. This for a combination of lenses is called the equivalent focal distance, but for the sake of brevity the term "equivalent" is hereinafter omitted.

All objectives of the same name and size are supposed to have the same focal distance, which is usually stated by the maker; but slight variations in their manufacture give different values for it, and it is therefore best to measure it for each one.

For a simple convex lens, double or plano convex, the position of the optic centre

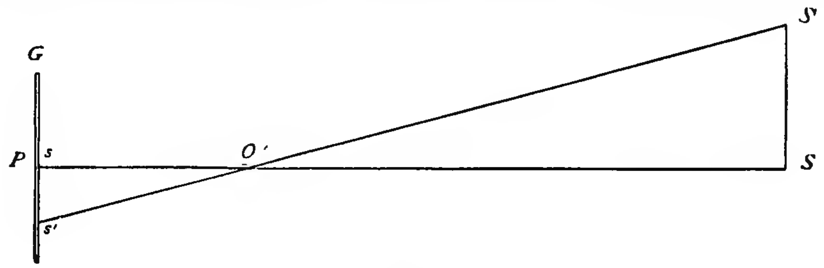

FIG. 14.

is easily observed, and it is only necessary to measure, with a scale of equal parts, the perpendicular distance from it to the rough surface of the ground-glass; but for a double combination lens this operation is evidently impracticable and any of the following methods may be employed:

I. Set up and level the camera; place a staff, S, Fig. 14 (a horizontal projection), vertical and about 75 yards from G, the rough surface of the ground-glass; and another staff, S', also vertical about 10 yards from S, and so that SS' shall be perpendicular to PS. Having drawn a vertical line through the middle point of G, focus S upon it; measure PS,—the horizontal distance between G and S,— SS' and ss' : then from the similar triangles thus formed, Os or $OP : ss' :: OS : SS'$; $OP : ss' :: OP : ss'$; whence $2OP : 2ss' :: OS + OP : SS' + ss'$; by substitution, $OP : ss' :: PS : SS' + ss'$; therefore

$$OP = \frac{PS \times ss'}{SS' + ss'}.$$

e.g.: $PS = 75$ yards, $SS' = 10$ yards, and $ss' = 2$ inches; then $OP = \frac{75 \times 36 \times 2}{10 \times 36 + 2} = 14.92$ inches, very nearly, near enough for practical purposes. ss' can be measured either by exposing a sensitive plate and applying a scale of equal parts to it after development; or on the rear surface of the ground-glass, by carefully marking off on the edge of a

strip of white paper, the distance ss', and applying the scale; in any case, ss' and SS' should be measured in the same direction.

II. Having set up and levelled the camera, focus two points, as S and S', Fig. 14, 75 or 100 yards distant, and so disposed that their images on the ground-glass will be separated horizontally by a distance of about one third of its breadth. Make one image, as s, coincide with the middle vertical of G; and measure the distance ss'. Remove the camera; set up a transit or other angle-measurer at O, and measure the angle $SOS' = sOs'$, which denote by a; then

$$OP = \frac{ss'}{\text{tang. } a} = ss' \text{ cot. } a.$$

III. It is a well-known principle of optics that when the sizes of image and object are equal, the distance between them is four times the equivalent focal distance of the lens. Therefore, to measure OP: construct upon a sheet of white paper two right lines at right angles to each other; from the point of intersection as a centre, and with a radius of about one third of the shorter side of the ground-glass, describe the circumference of a circle, and fasten the sheet to a vertical wall or board; set up and level the camera in such a position that the image of the centre of the circle shall be in the optic axis,—the middle point of the ground glass when the objective-slide is in its normal position (see par. 14); and focus so that the construction on the paper, and its image, shall be of equal size, which condition can be ascertained by the application of a pair of dividers. Remove the objective and measure the distance from the ground-glass to the paper: one fourth of this distance is the required value of OP. This method usually requires a long camera, or an extension piece in front to hold the lens.

Whenever the focal distance is determined by Method I. or II., the positions of the parts of the camera, especially that of the back or front according to which one of these is made to traverse, should be indicated by marks carefully made upon the metal mountings, so that this adjustment can be readily made at any time.

By Method III., the position of the optic centre can be indicated upon the objective-tube by first replacing the latter, and then setting off from the paper one half the distance between paper and ground-glass, or $2OP$. It can also be indicated in Methods I. and II. by means which will suggest themselves.

14. *The Determination of the Horizon, or HH'.*—First find the middle point of the ground-glass,—which is readily done by drawing its two diagonals,—and through it draw two right lines parallel to a horizontal and a vertical edge respectively of the ground-glass frame. These edges should be perpendicular to each other; but if, through faulty construction of the frame, they are not so, then set up the camera and level it, and, with the aid of a carpenter's level, locate the horizontal line which passes through this middle point, and draw it; and also draw a vertical line through the same point.

The camera being set up and levelled, focus on a distant point, previously ascertained with a surveyor's level to be on a level with this horizontal line, and move the objective-slide up or down until the image of the distant point is cut by the horizontal. The objective, or objective-slide, is now in its *normal position*, and HH' will evidently pass through the middle point of a view taken under these conditions.

It is apparent that the amount of sky or of foreground in the view can be changed by raising or lowering the objective, and that this condition usually enables the surveyor to adjust his camera so as to include all the features required, whether the station be elevated or depressed with reference to the surrounding features; but in moving the objective-slide from its normal position, HH' will no longer pass through the middle point of the view, and some means are necessary for determining its true position.

A simple device for determining HH' under these conditions is as follows: The right-hand part of Fig. 15 represents a vertical section through the optic axis, G the

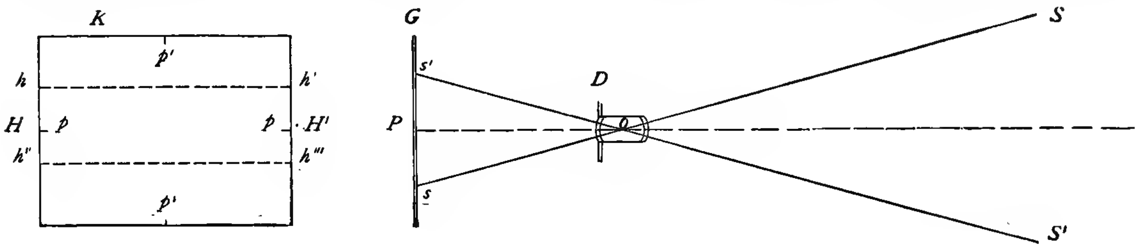

Fig. 15.

ground-glass, D the objective-slide; and K represents the plate-holder, or, in case of a small plate, the kit (a frame fitting within the plate-holder) used to hold it. (See also H, Fig. 9.) When D is in its normal position and an exposure made, HH' is marked upon the negative, and therefore upon the print taken from it, by means of the needle-points p projecting from the middle points of the vertical edges of the holder or kit, and immediately in front of the sensitive plate. The points p' similarly mark the position of the middle vertical. The author has made use of fine cambric needles, reduced to about one third of their length, and heated, before insertion, to prevent breaking when the plate was pressed against them. For needles, metal triangular pieces might be substituted, the plate resting upon them. The true positions for the needle-points may evidently be found in a manner similar to that described for drawing the horizontal and vertical upon the ground-glass, or by other simple means. It is apparent that when D is raised or lowered, HH' will rise or fall an equal distance, and will be found at, say, hh' or $h''h'''$. To measure this vertical interval, Hh or Hh'', construct on the front of the camera a scale of equal parts, as shown at c in Fig. 16, and an index, which may be an edge of the strap r, on the slide will then mark the division denoting the required interval. The index should mark 0 when the slide is in its normal position, and the divisions above and below be considered as positive and negative respectively. By this construction HH' may be fixed upon any negative or print by setting off vertically in the proper direction, from each of the marks produced by the needle-points p, the distance measured by this scale, and joining the outer extremities by a right line.

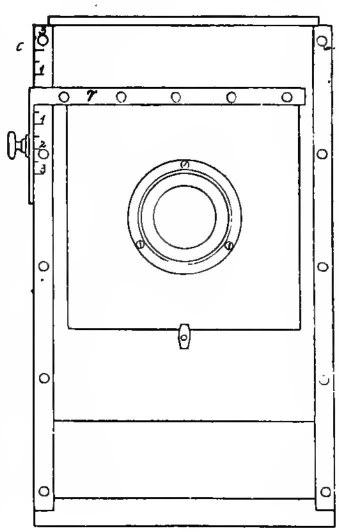

Fig. 16.

It is apparent that any truly-horizontal line of a print or negative may serve for the measurement of horizontal angles; but the needle-points usually mark HH' through the middle point, and since paper prints are subject to distortion by chemical manipulation (see also par. 32), this position is likely to give more exact measurements. (For another method of determining HH', see close of par. 20.)

15. *Measurement of the Field of View.*—The extent of the field of view of the camera is an important element in surveying, since it determines the amount of the visible landscape that can be included in the photograph. It is measured, horizontally, by the angle included by right lines drawn from the optic centre to the extremities of HH'; and, vertically, by right lines from the optic centre to the extremities of the middle vertical of the ground-glass. The horizontal field of view is therefore twice the angle of which the tangent is $\frac{1}{2}\frac{HH'}{OP}$, and the vertical field is twice the angle of which the tangent is $\frac{1}{2}\frac{\text{middle vertical}}{OP}$; e.g., if $HH' = 9.6$ inches and $OP = 16$ inches, then

$$\frac{1}{2}\,\frac{9''.6}{16''} = \frac{9''.6}{32''} = 0''.3,$$

which practically is the tangent of 17°; $\therefore$ the horizontal field of view $= 34^\circ$.

This element may be determined graphically by constructing the angle on paper, and then measuring it with a protractor.

This is evidently the field of view for the particular camera to which the objective is attached, and a like construction gives it for any sized plate. To measure the field of view of the objective; use, instead of $\frac{1}{2}HH'$, a radius of the circle of light formed on the ground-glass, when the objective is attached to a camera larger than that to which it is suited.

Owing to the defects, due to development, nearly always existing along the edges of a plate, it is advisable in the above measurement to make an allowance of 2° or 3° for any plate. It is seldom that the vertical field is insufficient.

When haste is an important element, a wide-angle objective, of which the focal distance is much less and the field therefore much wider, may be used to great advantage. In Dallmeyer's 8×10 rapid rectilinear, OP is $13''$, affording a field of about 38°; while in his 8×10 wide-angle rectilinear, OP is $7''$, and the field is about 54°; therefore with the former, 10 plates would be required for a complete tour of the horizon; but with the latter, only 7 plates are needed.

16. *Test of an Objective for Distortion.*—To ascertain beyond a doubt that the objective is free from distortion throughout the entire field of view assigned to it, a modification or extension of the method used for measuring OP (par. 13) may be employed. Thus, in Fig. 17, a horizontal projection, place additional vertical staves at S'', S''' .... in SS' prolonged, the number and location being such that their images s'', s''' ... are well distributed along any line of G, one of them being near each of the vertical edges of the latter, and s being on the middle vertical.

Measure, horizontally, the distance from S to each staff; expose a plate, and, on the developed negative, project s, s' ... into HH'; from OP and the tangents ss''', ss^{iv} .... determine the angles sOs''', sOs^{iv} .... ; then compare these angles with SOS''', SOS^{iv} ...,

computed from the radius OS and tangents SS''', SS^{iv} .... The corresponding angles of the two sets should be equal. Or simple proportions may be used; thus, ss''' should be to SS''' :: Os, or OP, : OS ....; or an angle-measurer may be substituted as in measuring OP.

To be very accurate, revolve the objective 90° and repeat the operation.

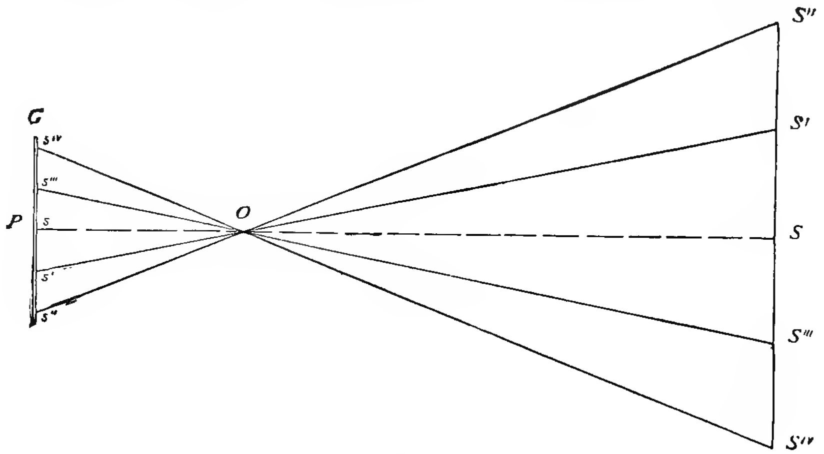

FIG. 17.

Another method is as follows: Subdivide a rectangle, constructed on a flat surface, into equal squares; make the dispositions prescribed in III., par. 13, for paper and camera; and compare the different sides of the squares with their images. When a value for OP, less than that given in III., par. 13, is employed, it is only necessary that these images should be proportional reductions of the original squares. For convenience, the sides of the rectangle should be proportioned to the edges of the ground-glass; and, in focussing, their images should lie near these edges.

17. *Exposure, Development and Printing.*—Before proceeding to the Field-work, a brief description of the operations which result in a "view" photograph suited to surveying purposes may be found serviceable. For fuller details of manipulation, reference may be made to Manuals of Photography.

(*a*) *The Exposure.*—The camera is placed firmly upon its tripod, levelled, and pointed toward the subject; the back or front, according to which of these is made to traverse, is then adjusted to the mark corresponding to the focal distance (see close of par. 13); the objective-slide is so disposed that the image will occupy the most favorable position upon the ground-glass, and the index number of the slide is noted. The proper stop is then placed in the objective; the latter is capped to exclude the light, and the plate-holder, containing the sensitive plate, is inserted. The levelling should now be verified. The shield is then withdrawn, the cap is removed for a period corresponding to the sensitiveness of the plate, and atmospheric and various other influences soon observed in practice; the shield is now replaced. With a particularly rapid dry plate (sensitiveness 25) and a bright day, try the use of the smallest stop and an exposure of about half a second. (See also par. 23.)

(*b*) *The Development.*—A printed circular, giving the process of development best suited to each of the many kinds of dry plates manufactured, usually accompanies each box of plates; but the following is a simple and good one:

In the dark-room, remove the plate from the holder and wash it for half a minute under the tap; then develop with the following solutions:

No. 1,—a filtered sat. sol. of oxalate of potassa + a few drops of oxalic acid.

No. 2,—a filtered sat. sol. of sulphate of iron + a few drops of sulphuric acid (C. P.).

To four parts of No. 1 add one part of No. 2, first diluting each separately with half its bulk of water; place the plate, film up, in a shallow porcelain or japanned tray, and cover it quickly with this developer; keep the liquid in motion by gentle rocking, and develop until some of the details are visible on the glass side; then wash the plate a minute under the tap, and place it, film up, in the fixing-bath, composed of hyposulphite of soda 1 part + alum $\frac{1}{16}$ part + water 5 parts; when clear, that is when the white film has disappeared, leave it a few minutes longer in this bath, and then place it in running water, where it should remain at least one hour (five hours are better). The resulting negative is then permitted to dry spontaneously. A few drops of a 15-gr. solution of bromide of potassium in water, added to the developer, will sometimes result in giving more of the finer details; and distant mountains may be brought out with greater clearness by brushing them once or twice, using a camel's-hair brush, with a 5-gr. solution of this bromide during the development. A clearing solution is sometimes needed after fixing; but is oftener needed with pyro than with iron developers.

(*c*) *The Printing.*—Albumenized paper is lightly rubbed smooth with a Canton flannel pad; then sensitized by floating it about 2 minutes on a silver bath of 50 gr. to the oz.,—care being taken not to let the solution touch the back of the paper. It is then, after thorough drying, exposed in a wooden box to the fumes of strong ammonia, for from 30 to 40 minutes—the shorter period in warm weather. The negative having been placed, glass face outward, in a printing-frame, Fig. 18, a piece of sensitized paper of suitable size is laid carefully on the film; the back, *b*, is pressed down and secured, and the frame is exposed facing the sun, or bright sky, until the lines of the print are slightly bronzed, which condition may be observed by means of the hinged sections of the back. When a sufficient number of prints have been made, they are washed in running water for about 5 minutes; then put in a bath of salt 1 part + water 50 parts, until the lines turn red; they are then "toned" with chloride of gold, 1 gr. to each sheet of paper, made by adding this to a solution of borax 1 part + water 80 parts—a sufficient quantity to contain the prints; they are left in this bath and kept continually in motion until the red lines turn black; then washed a few minutes, and placed in the fixing-bath, same as for plates, and left 10 minutes. They are then placed in a strong solution of salt and water for 10 minutes, and finally are washed for about 5 hours in running water. After drying, trimming and mounting, they become the ordinary landscape photographs.

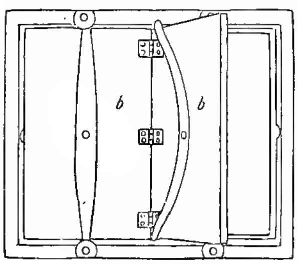

FIG. 18.

Other and simpler processes for printing, such as the "blue-process," using a negative to print from, may be resorted to; and in most cases afford results sufficiently good for the plotting.

THE FIELD-WORK

18. *General Considerations.*—The general principles of ordinary surveying apply in the field-work; the main conditions to be fulfilled in order to ensure satisfactory results being the selection of suitable points of observation, or stations, and the proper distribution of the stations to obtain favorable intersections and to economize time.

The three following methods of working are described:

I. With the Camera, when the triangulation has been established.

II. With the Camera and Hand-compass.

III. With the Camera alone.

19. *Selection and Distribution of Stations.*—The photographs obtained should embrace, as far as possible, all of the features to be represented upon the finished map. This is of easy accomplishment when commanding points exist, and easier than might at first be supposed when the tract to be represented is comparatively level. What is considered covered ground in ordinary surveying presents no greater difficulty here; e.g., in the case of a heavily wooded section of the tract, in working with transit or compass, salient points only of the outlines are usually exactly located from the commanding stations, the rest being filled in by eye; while in photographic work, with usually no additional labor in the field, every visible curve and detail of these outlines may be plotted from the photographs should it be desirable so to do.

As in ordinary surveying, meanders with prismatic compass and note-book are occasionally needed, more especially to prevent multiplication of photographs in cases of views being obscured by the interposition of abrupt salients or spurs; and, as in the case above given, to represent roads or paths through the covered ground.

The intersection of lines very oblique to each other does not fix a point with clearness;

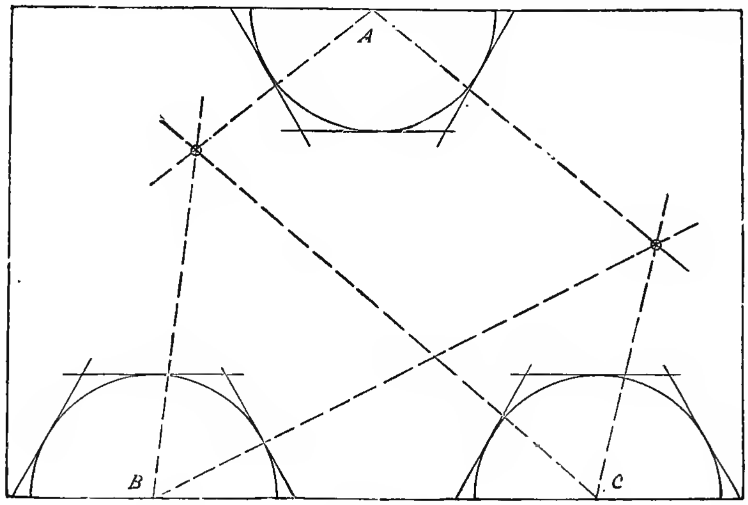

FIG. 19.

the most favorable intersections, in the case of two photographs of the same section, will be afforded when the photographs are taken from stations, so disposed with reference to each other, that, in the exposures, the optic axes produced would intersect at a right angle; between these limits there is a wide range for selection, and on this selection, or choice of stations, the successful result greatly depends. For an ordinary tract of, say, 3×4 miles in extent, three stations disposed, as shown in Fig. 19, at the vertices A, B and C

of an approximately equilateral triangle, would doubtless give the best result. If the borders do not contain commanding points, three interior stations similarly disposed might prove equally good; but, on account of the resulting wider field at the different stations, more plates would usually be needed.

An important element in this selection, when exact work is required, is that check-lines shall be afforded for all important points; in other words, and as above illustrated, that each of these points shall be found upon one photograph from each of at least three stations.

As to economy of time, and that of plates also may be added, this rests principally upon the judgment exercised in the grouping of the stations. It is unnecessary that any point to be represented should appear oftener than as above stated; and practice shows that the best arrangement of the stations is in groups of three, each one of a group facing, and the exposures at that station being confined to, the same section of the tract. An application of this principle is afforded in selecting for stations the vertices of triangles in a triangulation system; a complete tour of the horizon would then usually embrace several triangles.

20. *First Method—With the Triangulation Previously Established.*—The method of development, from a measured base, of a system of triangles or quadrilaterals, of which the vertices are exact positions of prominent points, is too well known to require a description here; it is only necessary that this system should be adapted to the present purpose,—that the positions of the stations should meet the requirements stated in par. 19.

The stations having been established, and the photographer furnished with a tracing of the triangulation sheet in which they are alphabetically marked, the work is begun preferably at one which has an exceptionally good command; for this may lessen the number of exposures which might otherwise be required from one or more adjacent stations, without diminishing the number of checks required for good work. A tour of the horizon, or so much of it as may be needed, is then made, working systematically here, as at all other stations, from left to right. The exposures are recorded in their order of completion V_a^1, V_a^2, V_a^3, . . . , the sub-letter referring to the station. Since the plate-holder shields are numbered in the natural order 1, 2, 3, . . . ; if the contained plates are exposed accordingly, mistakes will be obviated, means will be afforded in the plotting, as will be hereinafter shown, for properly locating the different views, and the work can be plotted by those not present at the field-operations.

The following-described method of working and form of record were employed with good results by the author:

The camera is set up, pointing in the general direction of the left-hand view; adjusted to the focal distance; levelled approximately; then carefully pointed so as to include the objects on the extreme left; the objective-slide is then adjusted so that the vertical field shall include the important features, and its index number is recorded. The plate-holder is now inserted; the camera levelled accurately; the exposure is made, and the bearing of the optic axis as indicated by the compass is also recorded.

The camera is then turned to the right for the next view, and in this operation care is taken to include in the second view the objects on the extreme right of the field in the first; this is necessary for reasons given in par. 15, and because this double representation serves a purpose in the plotting (see par. 26); a second exposure is then made with the same precautions as before observed, and so on for the remaining views.

The form of record employed is here given.

STATION.	VIEW.			REMARKS.
	No.	Index Number.	Bearing.	
A	1	0	195½°	
	2	0	227	
..	..	..	..	
B	1	− 2	84	

The index number of the objective-slide is frequently the same for all views taken at any one station.

In this instance, a detached hand-compass was used; as soon as the plate-holder was withdrawn, the bearing of a point of the image of any prominent object, cut by the middle vertical of the ground-glass, was taken, and a description of the point was recorded either verbally or by a rough sketch (see Fig. 20), sufficiently intelligible to be recognized in the developed negative. Since this vertical extended throughout the field, no difficulty arose in finding some object projected upon it and well disposed for the purpose. It is apparent that the bearing indicated by an attached compass immediately after the exposure, and before the camera is disturbed by withdrawing the plate-holder, is likely to be more exact.

From a consideration of the foregoing, it is seen that with suitable appliances the camera could be automatically checked in its revolutions, for the different fields in succession; or, a horizontal limb might be added and the arc of revolution measured by it, thus requiring but one bearing for a set of views from any station.

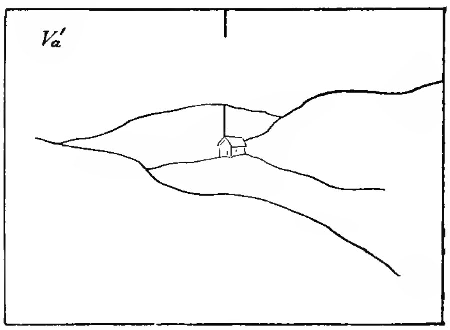

FIG. 20.

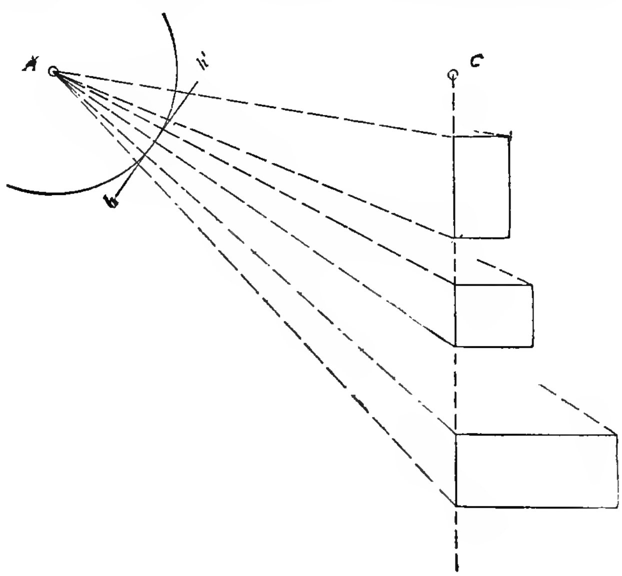

FIG. 21.

A judicious use of the hand-compass may frequently serve to diminish the number of views otherwise required. Thus, in Fig. 21, the buildings are located by means of the view from station A, supplemented by the compass bearing of the front line taken from any point of it, as C, which has been fixed by interpolation, or otherwise, from stations

already determined. This line evidently intersects the lines of direction from A in required points of the buildings; similar applications of the compass will suggest themselves.

The needle-points pp', Fig. 15, could be dispensed with and the horizon, or HH' of a print, be otherwise determined as follows: At the station from which any view is taken, measure with a hand-clinometer the angle of elevation or depression of a prominent point, situated near the right and left vertical, respectively, of the field of view—a third point would serve as a check, and its vertical angle should therefore be measured take also from this station and from at least one other station the compass-bearings of these three points, so that their plan may be constructed. Set off, in the proper direction from the image of each point on the print, a vertical equal in length to the natural tangent of the corresponding angle $\times$ distance from station to its horizontal projection; then the right line joining the outer extremities of the verticals will be the required horizon. It is apparent that, by a simple graphical application of the "three-point problem," the three compass-bearings taken as here described might also serve to orient the projected horizons on the plot.

21. *Second Method—With Camera and Hand-compass.*—There being no previous tri-

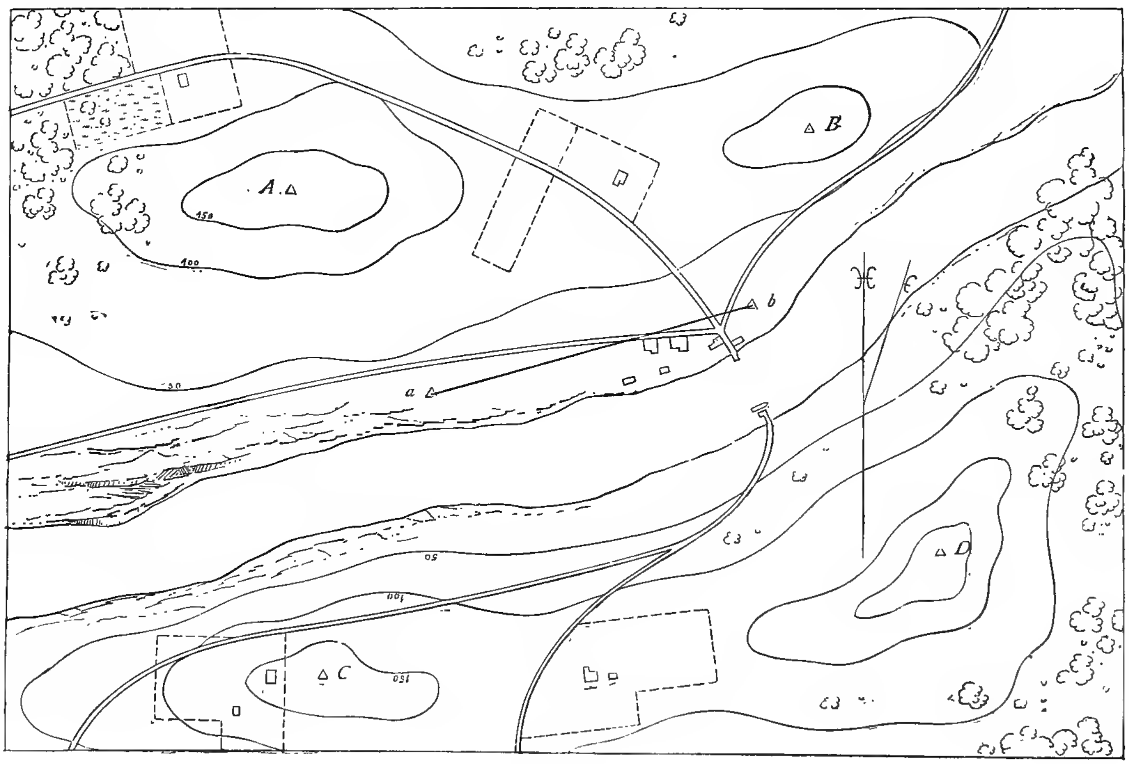

FIG. 22.

angulation in this case, the stations are determined by intersecting compass bearings taken as the work progresses, the details of the photographic work conforming to those of Method I.

Thus, as illustrated in Fig. 22, beginning at A, a tour of the horizon, or so much thereof as may be needed, is made; and, if no natural signal exists by means of which the camera's position at A may be subsequently recognized from at least one other station, as B

or C, an artificial signal is set up; this may be a white or black flag according to the nature of the background as viewed from the second station, whether earth or sky respectively. Proceeding to B, another tour is made and the bearing of A taken. If a suitable position for the camera at C or D can be discerned from B, its bearing is also taken; and, as a rule, ***on reaching any station, the bearing of every other station to be subsequently occupied, or which has already been occupied, when its position can be discerned, should be taken and recorded.***

Interpolation by compass-bearings is of much use here; e.g., referring to the preceding figure, C is fixed if from it the bearings of A and B are taken, since these bearings if plotted at A and B and produced must intersect at C.

The bearings evidently serve to locate the stations in their proper relative positions, the only element lacking to plot to any required scale being the exact length of some line represented in the view. This element may be supplied, as in ordinary triangulation, by the measurement of a side as AB; or a shorter distance as ab may be measured and the points A and B fixed by intersections; in either case the measured distance is plotted according to the desired scale, and is the base of development for the plotting.

Plotting to scale may also be effected as illustrated in Fig. 23. Assume two points, as A and B, in their true directions with reference to each other, but with the intervening distance taken at pleasure; then, starting from these points, plot the extremities a and b of a distance which has been measured on the ground; also plot some contained point, as C, used as a station. Construct the triangle ABC; and from a set off toward b, ab' = the measured distance reduced to the required scale; then from A set off

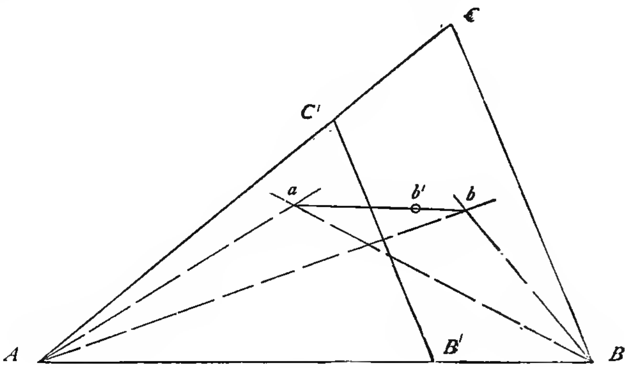

FIG. 23.

$AB' = \dfrac{ab' \times AB,}{ab}$ and through B' draw a line parallel to BC; B' and C' thus determined are the required positions of B and C for the given scale, and the triangle $AB'C'$ forms a basis of development for the plotting.

22. *Third Method—With Camera only.*—In this case, it is best to start from a measured base. With an attached compass, the bearings of OP for the different views serve to orient the views on the plotting sheet. The case in which a compass is used for orienting only, and that in which it is dispensed with altogether, require no further description than that given for the plotting in "Special Cases of Orientation," par. 26. In regard to the stations, careful attention should be paid to occupying those points only which may be clearly recognized in the views taken from adjacent stations; and in this respect it is best to have at all stations visible signals, natural or artificial, which present a strong contrast to their surroundings. With ordinary care this method is quite accurate, and may often prove the only one available; but, on account of the independent data afforded, the addition of compass-bearings, of at least the stations, is advisable.

23. *Best Time for the Field-work.*—As to the season of year: for wooded tracts, the best time is undoubtedly the Spring or Fall, when the leaves are off the trees and the range of view is thereby very much increased; the Winter season also often affords favorable opportunities. For tracts not wooded, or with scattered trees only, there is but little choice. The dry plates now made can be used in all seasons with equally good effect.

As to the time of day: the main rule to follow in visiting the different stations is to so arrange the route, that at any station the camera may be pointed toward the sun as little as possible. The most favorable direction of the sun's rays is from the right or left, and rear, of the instrument; in some cases, however, as in that of hilly or undulating ground, it is of advantage to have them in a direction nearly perpendicular to the optic axis, thus giving the elevations and depressions greater prominence by the addition of their visible shades and shadows. In this respect, a little observation of the relative degrees of clearness with which various portions of a landscape are seen, under different degrees of inclination of the sun's rays, will prove of value. Bouguer's table of the intensities of solar rays corresponding to different altitudes of the sun is very instructive here, and is given below; 10,000 represents the intensity in a perfectly transparent atmosphere.

Sun's Altitude.	Intensity.	Sun's Altitude.	Intensity.
0°	6	20°	5474
1	7	25	6136
2	192	30	6613
3	454	40	7237
4	802	50	7624
5	1201	70	8016
10	3149	90	8123
15	4534		

Since the actinic effect of solar rays is directly proportioned to the length of time during which they act, the variations above given must be mainly due to the different distances traversed in the atmospheric envelope; for the same reason, and because of the less density of the atmosphere, exposures made in mountainous or elevated tracts should be of less duration than at the sea-level. According to this table, exposures made, for example, at 8 A.M. and 4 P.M. should be of the same duration; but, in practice, it is found that, owing to the comparatively greater amount of moisture at the latter hour and the consequent partial absorption of the ultra-violet rays, the second exposure should be of greater duration. It is also observed in landscape-photography that the actinic effect of light reflected from white clouds is even more powerful than that of a perfectly clear sky; bringing out the details of deep valleys with great clearness.

As to the weather: a very clear atmosphere frequently exists in Winter, and usually after a storm during all seasons.

On account of the extreme rapidity of the field-work as compared with that of any

of the other methods of surveying, it is seldom that the surveyor may not take advantage of the most favorable conditions and circumstances.

THE PLOTTING.

24. *General Considerations.*—The plotting of a survey consists of the two following distinct operations:

I. Constructing the plan, or the horizontal projections of the different points and lines;

II. Determining the heights of points with reference to the datum plane; and, as already described in par. 6, the result is the complete determination of these elements.

It seems hardly necessary to state here that the principles defined and illustrated in Section I., and there confined to a perspective drawing, apply directly to a photographic representation. Thus, in Fig. 24, V and V' represent respectively the relative positions, with reference to the point of sight, of a perspective drawing and a photographic representation; they are vertical and parallel, equidistant from O, and the right line POP' pierces each at its middle point; and since any point as D is projected by the same visual ray in d and d', which are equidistant from the middle points of V and V', the two views are similar. Another consideration; since the maps are seldom constructed to a scale greater than $\frac{1}{5000}$, and because OP seldom exceeds 15 inches, $\frac{1}{333}$ of an inch to this scale, it makes no sensible difference in the plotting whether in the field-measurements a station-point is directly beneath the optic centre of the lens, or beneath the ground-glass; to be strictly exact, however, it is apparent that the camera should be so constructed as to revolve about a vertical axis through the optic centre; and that in setting it up in the field the optic centre should be plumbed over the station-point.

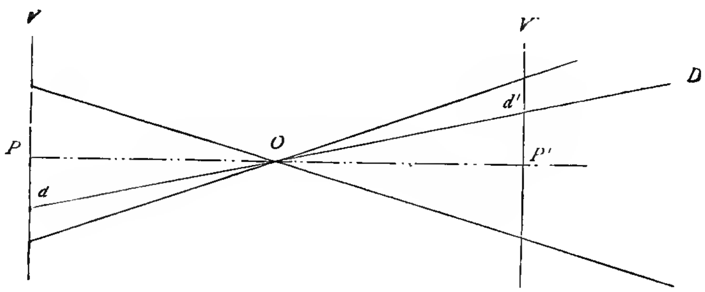

FIG. 24.

25. *To Construct the Plan.*—Assume two views, V_a' and V_b', Fig. 25, taken from the extremities of a given line, AB, and embracing the same objects Having plotted AB; from each extremity, with OP as a radius, describe circumferences as shown Draw the radii AV_a' and BV_b', making with the line of the magnetic meridian angles (20° and 280° in the figure), equal respectively to the bearings of OP for the views; then the tangents hh', at the extremities of these radii, are the required projections of HH'. This operation is termed the *Orientation of the views.*

All the points which are to appear in the plot having been projected on the respective horizons of the views (par. 5), and then transferred by means of dividers or otherwise, to the corresponding projections hh', any point is plotted by simply drawing right lines from the plotted stations through the transferred projections, and producing them to intersection; thus c, the intersection of Ac' and Bc'; and d, of Ad' and

Bd', are the required projections of the actual points C and D. If a view from a third station also contains these points, a check is afforded upon the accuracy of the plot.

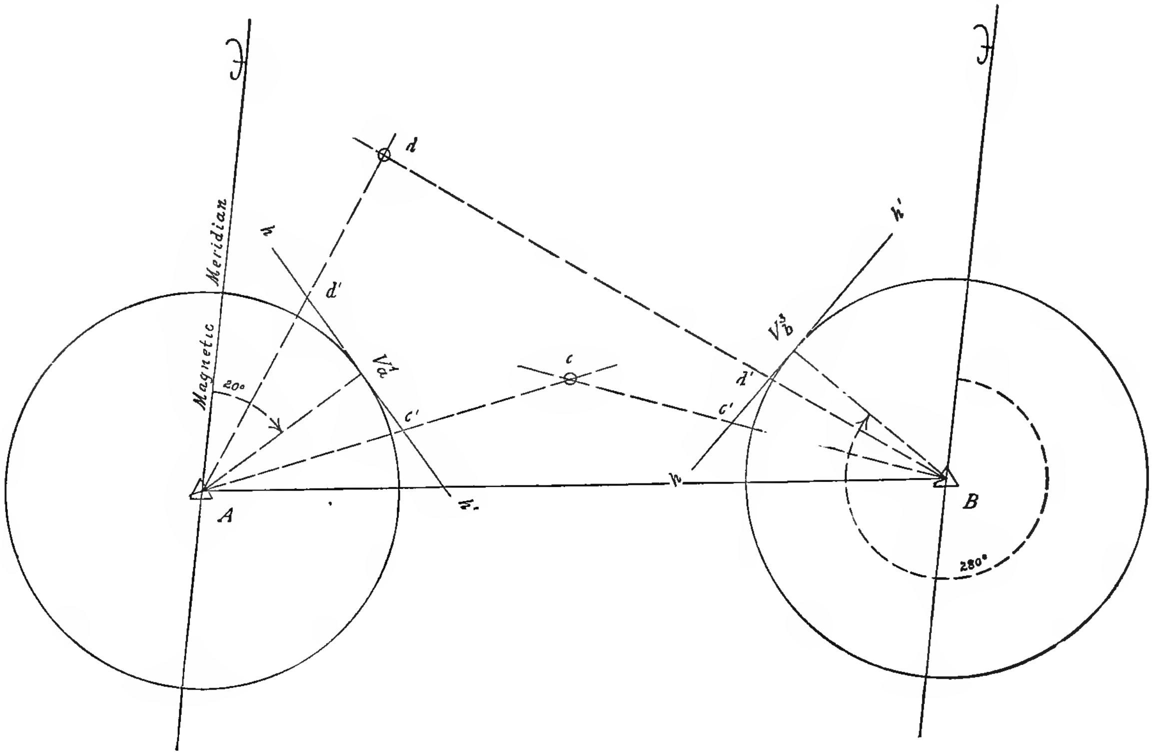

FIG. 25.

The plan of the entire survey is plotted in a similar manner; by first orienting all the views at their respective stations, and then fixing the required points by intersections as above.

26. *Special Cases of Orientation.*—I. Reference has been made to the necessity of having the views overlap slightly. This condition may be utilized, not only as a check in the plotting, but also to orient the views when compass-bearings of OP have been omitted. Thus, in Fig. 26, let o' and o'' be the representations of the same object on the consecutive views V_a^1 and V_a^2, and suppose the compass-bearing of AV_a^2 is unknown; to orient the second view, in other words to find the tangent-point of V_a: at d construct a tangent to the given arc, and on it set off dd' equal to the horizontal distance measured, on the second view, from the middle vertical to the image of O, join d' and A by a right line; then will V_a^2 be the tangent-point required.

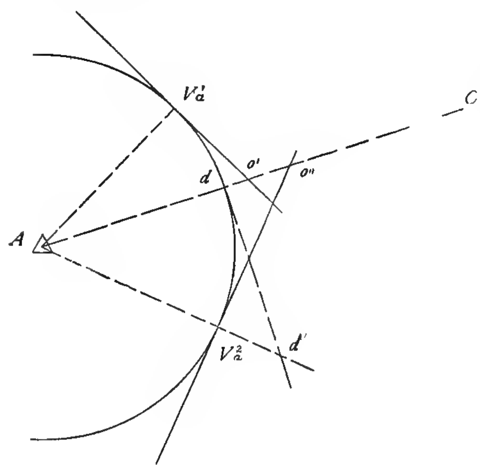

FIG. 26.

It is readily seen that in the other case, when the bearing AV_a^2 is known, the check referred to is afforded by o' and o'' being on the same line of direction.

II. When the compass-bearing of some line of direction other than the optic axis is given, as that of AO, Fig. 27;—*graphically*, plot at A the bearing of O as indicated; construct the tangent at p, and make pp' equal to the horizontal distance, measured on the print, from the projection of o to the middle vertical of the print; then Ap' will intersect the given arc at the tangent-point required: or, *trigonometrically*, since the horizontal distance pp', or Vo', is the tangent of VAo' to the radius $OP = AV$; tan. $VAo' = \frac{Vo'}{AV}$, and VAo' can then be obtained from a table of natural tangents; therefore first plot the bearing of O; then protract VAo, and the side AV will intersect the given arc at the tangent-point required.

III. In the case of confined space on the plotting-sheet: when the plotted station is near the border of the sheet, it may happen that the usual orientation would cause the work to fall outside of the sheet. This inconvenience can be avoided either by proportional reduction, or by reversing the position of the transferred horizon; thus, in Fig. 28,

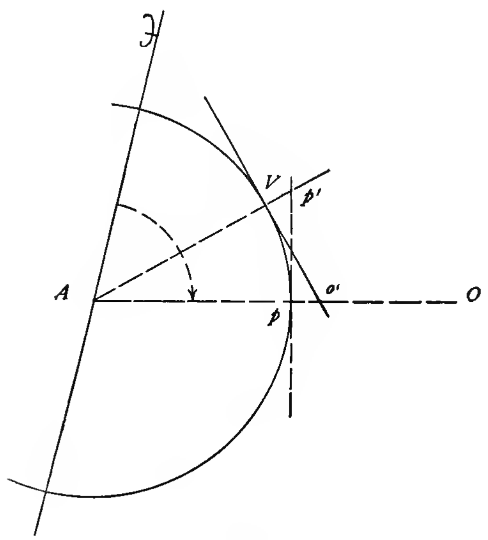

FIG. 27.

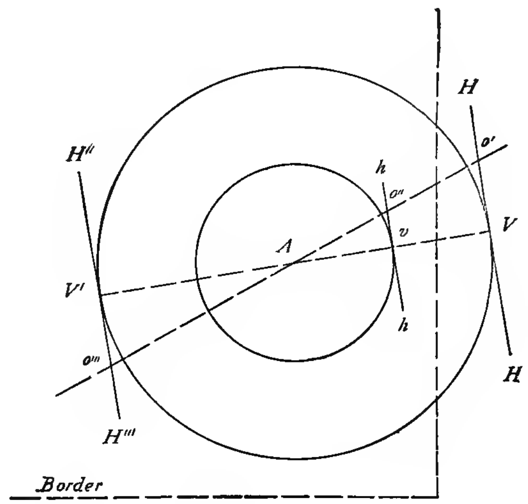

FIG. 28.

AV is the direction of OP, and HH' falls without the border. With $Av = \frac{1}{2}$ or $\frac{2}{3}$ .... of AV, as a radius, describe the interior concentric arc; at v, construct the tangent hh',—its length bearing the same ratio to HH' that Av does to AV: then with sector, proportional dividers, or otherwise, transfer the different horizontal distances, proportionally reduced, from the view to hh': the required intersections are then found as heretofore described.

Or, by reversing the positions of the horizons; thus, at V', the intersection of AV produced with the circumference, construct the tangent $H''H'''$. It is plain from inspection of the figure that in the transfer, the horizontal distances are now to be set off from V' in the reverse direction, e.g., o' on the view falling at o'''—the line of direction remaining unchanged. When necessary, the horizon can be both reduced proportionally and oriented in reverse on an inner circumference.

IV. Suppose the camera to have been used independently of the compass. Thus,

in Fig. 29, if the view from A contains both B and C, and that from B both A and C: draw a right line AB representing the horizontal distance from A to B according to the scale of the map. With radius OP describe arcs as shown. Project the images a, b and c on the horizons of their respective views. To orient the views: A, b', a' and B must be contained in AB; and C should serve as a check for accuracy. At t, the intersection of one of the arcs with AB, construct the tangent tg, in length = the horizontal distance from P (par. 4) to b', measured on the print; draw Ag; then will the tangent at p be the projected horizon, hh', of the view from A. $h''h'''$ is similarly constructed; and the subsequent plotting from these views is performed as already described for other cases. C being thus fixed, and the view from it embracing A or B, the plotting is extended as

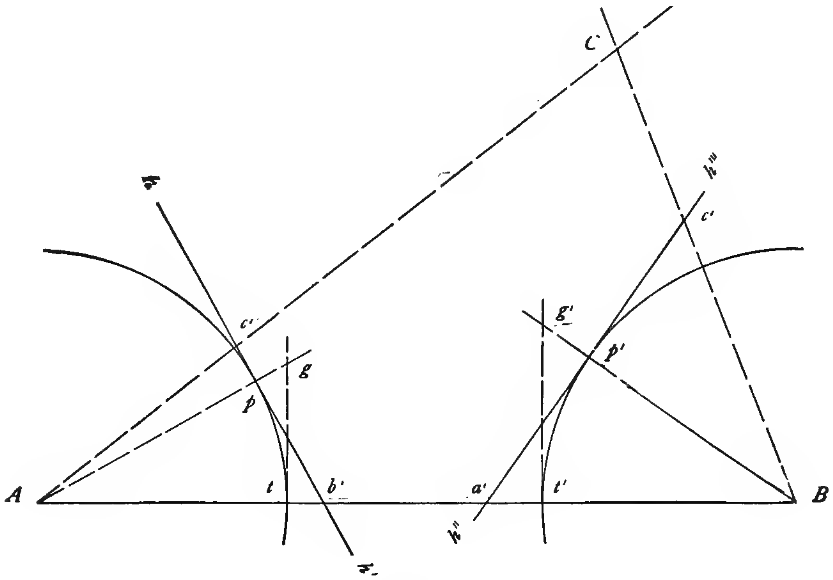

FIG. 29.

above described for the stations A and B; and so on throughout the survey. It is observed that stations to be occupied must be so located as to be readily fixed by intersections from those already occupied. Numerous opportunities for checking will evidently be afforded. (See also par. 22.)

27. *To Determine the Heights, or References.*—The general expression for the vertical distances of points from a datum plane is (par. 6) $H = \pm D$ tang. @; therefore, the plan having been constructed, in order to obtain the reference of any point from a view, it is only necessary to measure on the plot the distance from the station to the point and multiply it by tan. @.

A *reference* may be determined arithmetically, trigonometrically, or mechanically. *Arithmetically:* Referring to par. 6 and Fig. 8, tan. @ $= \frac{a'a}{Oa'}$; therefore measure $a'a$, or the vertical distance of the point from HH'; divide this by Oa' and multiply the quotient by the plotted distance OA'; the product is the required reference. *Trigonometrically:* $a'a''$, Fig. 6, being equal to $a'a$ measured on the view, make the construction indicated in this figure; measure $a''Oa'$ with a protractor; find the tan. of

this angle from a table of natural tangents, and multiply it by OA'. The *mechanical* determination is described in par. 29.

28. *Mechanical Measurement of Horizontal and Vertical Angles.*—To avoid linear constructions upon the negative or print, the author has devised a *tangent-glass*, which may be constructed as follows: select a flat, clear pane of glass, a trifle larger than the ground-glass of the camera; coat one face with white wax reduced by heat to a thin liquid; after the wax is poured on, it may be made to cover evenly by gently moving the glass back and forth over a lamp-flame. When cold, rule with a needle-point two right lines HH' and VV', Fig. 30, exactly perpendicular to each other, intersecting at the

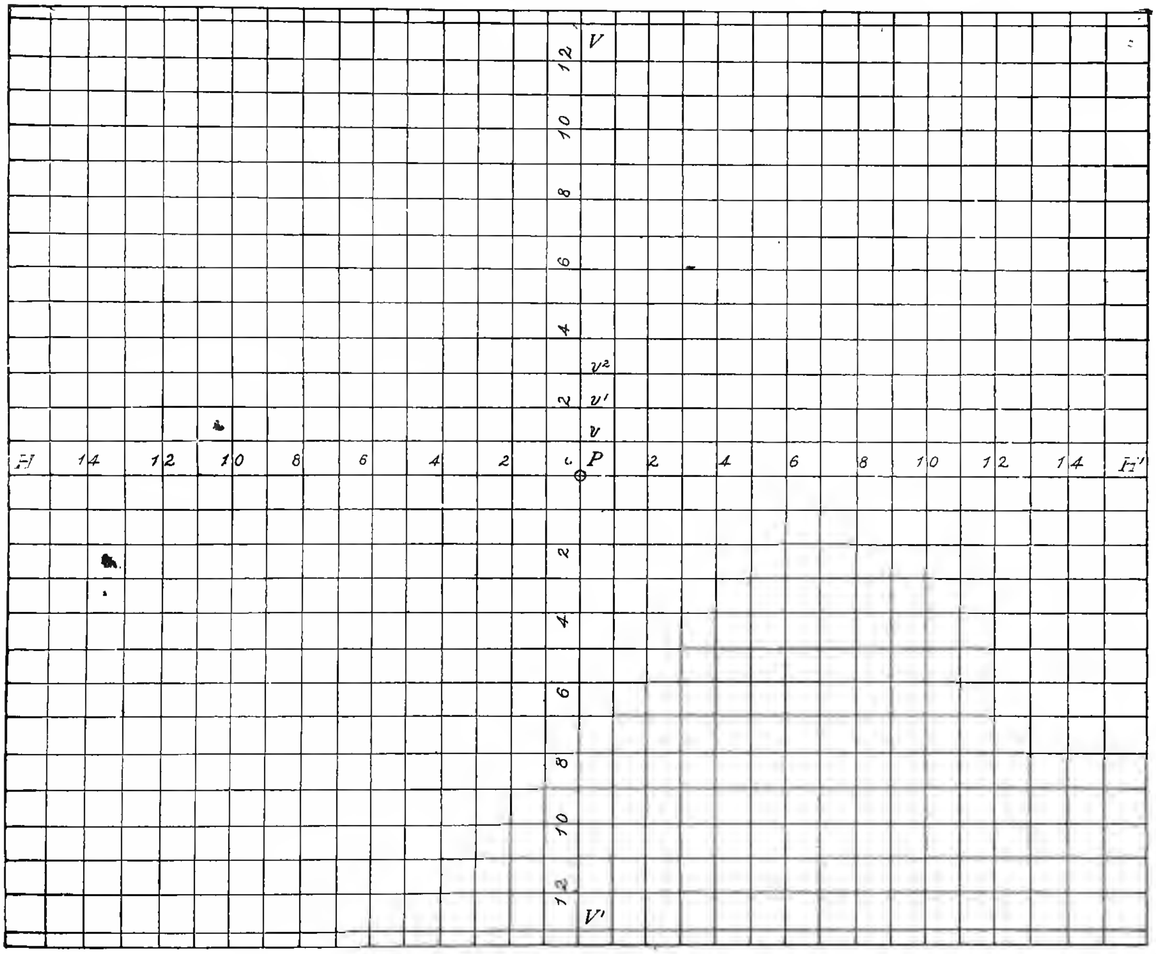

FIG. 30.

middle point P, and approximately parallel to the edges of the glass. From a table of nat. tangents, compute the tangents, to the radius OP, first of $\frac{1}{2}°$, then of $1°$, $1\frac{1}{2}°$, and so on, increasing by $\frac{1}{2}°$ for each computation, up to the number of degrees required to include half the vertical field of the camera,—full degrees only are shown in the figure. Set off these tangents, Pv, Pv', Pv^2 . . . . , on VV' in each direction from P; through their extremities, v, v', v^2 . . . , draw lines parallel to HH' and mark them as shown. Make a like construction of lines parallel to VV'. The ruled face is then exposed to the fumes of hydrofluoric acid, produced by adding sulphuric acid to fluor-spar in a leaden

dish. The dish may be made from sheet-lead, by bending up the edges to form sides about 1 inch in height, and should be a trifle smaller than the glass so that the latter may rest upon the edges and prevent escape of the fumes. When etched, the wax is removed and the tangent-glass is ready for use.

To ascertain a *horizontal angle*, it is only necessary to place the glass so that HH' shall cover the horizon of the print, and VV' the middle vertical; and then read off the required angle. This position of the glass is evidently assured by means of the images of the needle-points (par. 14);—also by location of a central point (par 20).

With the usual focal distance, the sides of the small rectangles are of sufficient length to admit of estimating to 6′ of arc, which for a distance of 1 mile represents about 9 feet; but with the aid of a microscope, and a scale of hundredths of inches, angles of 1′ are easily observed. For rough work, as in topographical sketching, the glass may be replaced by tracing-cloth,—the frame, Fig. 34, then coming in handily.

To ascertain a *vertical angle:* Referring to Fig. 31, HH' represents the middle hori-

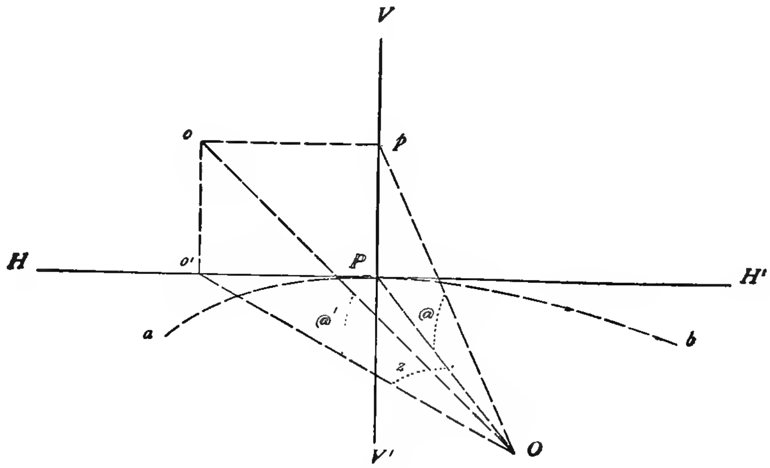

FIG. 31.

zontal, and VV' the middle vertical of the tangent-glass. ab is a circular arc in the plane HOH',—this arc evidently representing the intersection with this plane, of a cylinder of which the vertical axis passes through O, and of which VV' is the tangent element in the plane of the picture. From consideration of the figure, it is apparent that the only vertical angles which can be measured directly with the glass, on the view, are those of points contained in the plane of O and VV'; and that to read the vertical angles of other points, it is first necessary to find their tangents, in terms of the radius OP and the azimuths; which may be effected as follows:

Suppose the tangent-glass laid upon the view as described for the measurement of horizontal angles, and o and p to be points of the view on the same horizontal. Denote the angle pOP by @, and the angle oOo', which is evidently less than pOP, by @′; also let z denote the azimuth POo'. Then to obtain the required value for tan. @′:

$$\text{tan. } @ = \frac{Pp}{OP}; \ \text{tan. } @' = \frac{o'o}{Oo'} = \frac{Pp}{Oo'}; \ \text{but } Oo' = \frac{OP}{\cos. z} = OP \sec. z\,; \ \therefore \text{tan. } @' = \frac{Pp}{OP \sec. z} = \frac{\text{tan. } @}{\sec. z}; \ \text{and since } \frac{1}{\sec.} = \cos., \ \text{tan. } @' = \text{tan. } @ \cos. z.$$

Therefore on stiff paper or card-board (or the glass might be of sufficient extent for the purpose) make the construction shown in Fig. 32, of which the part subdivided into rectangles is a duplicate of the upper half of Fig. 30. From P, on the middle vertical, set off $PO =$ the focal distance; draw AB parallel to HH'; and produce the verticals (not produced in figure) to meet AB. Let o be any point of the view, and o'' the intersection with AB of the vertical passing through it: place a straight-edge, or scale of equal parts, on P and o'', and from P set off along the edge, indicated by the broken line, $Po''' = o'o$:

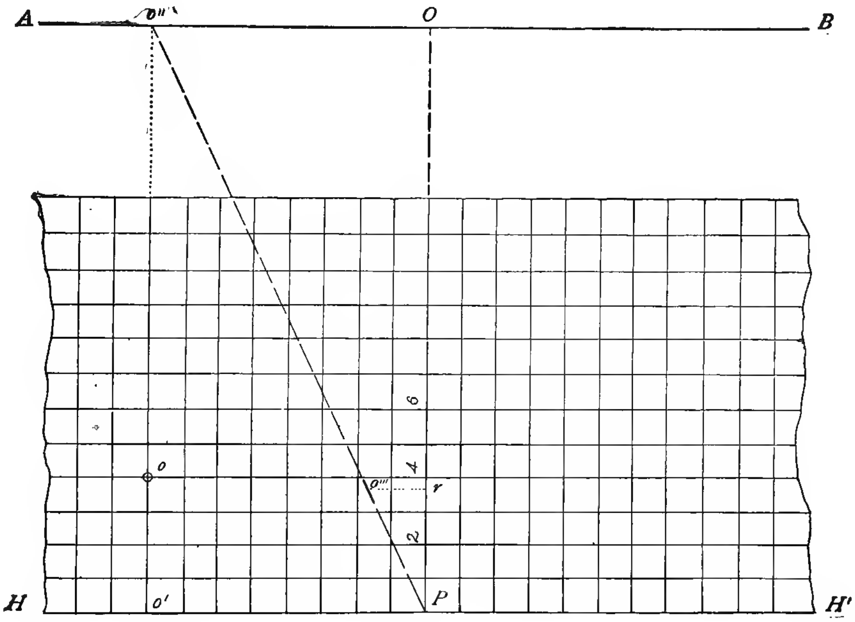

FIG. 32.

the required vertical angle of o will then be indicated by the horizontal passing through o''' For, Pr is the cos. of the angle $o'''Pr$; and, since cos. $= \frac{\text{base}}{\text{hypothenuse}}$, the base or tan. @$'$ = tan. @ cos. z, as above. This scale may be termed the *vertical angle scale;* and, for a short focal distance, may be conveniently etched upon the same glass with, and as an extension of, the tangent scale.

29. *Mechanical Measurement of Heights.*—The vertical angles determined, another scale which may be called the *scale of heights* can be used for the lineal measurements. Let CD, Fig. 33, represent the scale of distances used in the construction of the plan. From the 0 extremity as a centre, and with a convenient radius, describe a circular arc, which subdivide into half degrees (whole degrees in the figure), and draw radials as shown. To measure the height of any point, as O in the preceding figure: measure its horizontal distance on the plot; suppose this to be 1765 feet; at d, the 1765$'$ division of the scale, measure the vertical distance dd' to the radial indicating the vertical angle, in this case the $3^{\circ}.60'$ radial; which distance, reduced to the scale of the map, is the height required. The map scale itself may be used for this purpose, or a scale of equal parts can be substituted. For a map scale of $\frac{1}{5000}$, $\frac{1}{50}$-inch divi-

sions measure to within 9 feet, and estimation to half of this amount is easily had by eye; but the application of $\frac{1}{100}$-inch divisions, and the aid of a magnifying-glass, are advisable for more exact work.

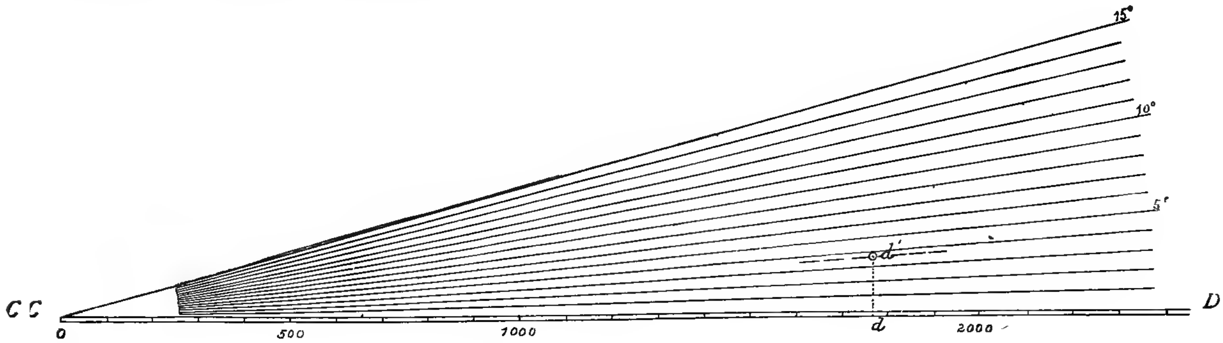

FIG. 33.

Great exactness may be obtained by doubling the length of the scale of heights, and using correspondingly double the distances measured on the plot.

When it is considered that, once made, these scales serve for all views taken with the same lens, the slight labor expended in their construction is certainly of little moment as compared with the facility afforded by their use. It would be advantageous to have the last one described engraved on metal.

30. *Reduction of References to a Datum Plane—The Contouring.*—In the determination of heights heretofore described, the plane of reference is the horizon of the station from which a view is taken; but, as in all topographical work, the measurements thus made for the different stations must all be reduced to a single or common datum plane. As previously stated, this is assumed as passing through or below the lowest point of the tract. The reduction is made in the usual manner, by adding to the measurements for any view the reference of the station at which that view was taken. To facilitate this operation, a form of record similar to the following will prove convenient:

FORM OF RECORD FOR REDUCTION OF HEIGHTS TO COMMON DATUM.

VIEW.	POINT.	REFERENCE.	REFERENCE OF STATION.	FINAL REFERENCE.	REMARKS.
		Feet.	Feet.	Feet.	
V_a^1	1	+ 102	+ 460	+ 562	
	2	+ 90		550	
	3	− 25		435	
*	*	*	*	*	

No difficulty arises in determining the reference in the fourth column; each station will appear on at least one of the views, and its reference is then obtained the same as for any other point; if it appear on two, a check is afforded. In the case of reciprocal views, the difference in elevation of the stations is readily ascertained from the

relative positions of the HH's on them; and when the same point is represented on views from two stations, the difference of its references, as measured on them, is evidently the difference in height of the stations.

As to the *contouring*, or plotting of contours: the reduced or final references having been noted beside the plotted points, the views are examined, and the conformation of ground carefully observed; the equidistant points are then marked on the plot, and the contours can be drawn with nearly if not quite as much precision as is usually attained in the "irregular methods" of contouring with other instruments. Additional points are supplied where needed for this purpose, and aid is derived from the condition, that all points cut by HH' on any view, have the same reference as the station from which that view is taken. From the fact that lines of direction, from stations to points of profiles, are tangent in plan to the corresponding contours, additional aid is afforded, and is frequently made use of in this part of the plotting.

31. *Suggestions in Regard to Plotting.*—The plotting of a triangulation is fully described in text-books of topographical drawing. The triangulation is plotted first; then come the orientation of the views at plotted stations and the construction of the plan; and, finally, the determination of the heights and the contouring. It will be found advantageous to fasten together in their proper order a set of views taken from each station, as the general view of the tract thus afforded gives a better knowledge of the work in hand, and the different points are more readily recognized; blue-prints serve this purpose. Each view should be marked as already described, V_a^1, V_a^2 . . . V_b^3 . . . so as to be quickly identified; and, as soon as oriented, the transferred horizon is to be similarly marked. It is well to number, on the views, all the points to be plotted, using like numbers for the same points both on the different views and for their projections on the transferred horizons. In the plotting by intersections, silk threads may be used if desired, instead of a straight-edge: each thread is fastened at one extremity to a needle thrust into a plotted station; the threads are then stretched over corresponding transferred projections and by their intersections fix the points. The references of points should be marked as soon as determined, beside the plotted points; and also recorded for reduction to a common datum (par. 30); for marking the final references, it is best to use a colored pencil. If possible, all important points should be checked by a third intersection; in fact, to secure a faithful representation, all the precautions that are observed when other methods of surveying are employed, should be taken.

32. *Preparation of Prints—Advantage in Use of Negatives.*—When the plotting is to be done from prints, or regular photographs, these should be carefully and equally dampened between sheets of blotting-paper, and then pasted, without rubbing, to stiff cardboard. As already stated, if the tangent-glass is used, no lines need be drawn upon them; otherwise, the horizons are drawn; and the points to be plotted, numbered as described in par. 31, are projected by verticals into their respective horizons. The horizons and any other desired lines may be printed from the negatives, by previously marking them on the latter with a fine needle-point.

Owing to distortion of the paper, frequently produced in the chemical manipulations, prints are less reliable than the glass negatives; therefore for exact work the latter should

be used. Sometimes, owing to unfavorable conditions of weather, or to improperly timed exposures, negatives do not show details with sufficient clearness for plotting purposes. This fault can ordinarily be remedied by using transparencies made from these negatives, preferably by the wet-plate process, and which will usually give fine definition. Better prints are often obtained from obscure dry-plate negatives by first making transparencies as above, and then, from the latter, making wet-plate negatives to print from. If the plotting is rapidly done, the paper prints, if excluded from light when not in use, may be employed without subjecting them to the process of toning, etc., and the consequent liability to distortion. In any of these operations, increased clearness in definition of sky-lines, hill-profiles and of other features, may be obtained, to almost any degree, by employing the usual process of retouching. Enlargements or reductions to any desired scale are readily effected by the ordinary photographic process. In applying the tangent-glass, it is more convenient to place the negative, film down, upon its etched face, and to rest both upon a strong plate of glass secured to an open frame, so disposed that the light may be reflected from a white surface upward through the glass to the eye. Fig. 34 represents a frame of this kind; placed in front of a window, and tilted at any desired angle, a sheet of white paper beneath serves as a reflector, and all but the reflected light is easily excluded by an opaque curtain conveniently disposed about the frame and draughtsman. With this arrangement, the details are clearly visible, and ruler and triangle may be applied without inconvenience. The negatives also should be labelled so as to be readily identified.

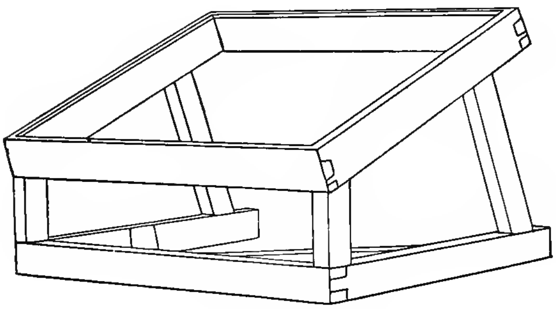

FIG. 34.

To prepare prints for accurate plotting, proceed as follows: Construct a duplicate of the tangent-glass lines on the film of an exposed, blank, developed and fixed dry plate, using a needle-point and marking prominently the extremities of HH' and VV'; print these lines on the sheets of sensitized paper intended for the views; and, in the subsequent printing, be careful to adjust these sheets so that the extremities of HH' and VV' will rest exactly upon the images of the needle-points on the station negatives. A variation from this operation, and one which may possibly give better results, is to expose each dry plate, for an instant, beneath the ruled negative, before exposing for the landscape-views; the tangent-lines will then appear in the latter. Care should be taken to have both sensitive plate and ruled negative rest evenly on the base and against one end of the plate-holder; in ruling the negative, HH' should be at the exact height of the needle-points, and marks made on the sensitive plate, in its first exposure, to show which edges of it to place up and against the end for the view.

33. *Choice of Scale—Accuracy Attainable.*—As a result of experience it has been found that the scale of $\frac{1}{6000}$, or of $\frac{1}{4800}$, is the most convenient for photographic work. A smaller scale would naturally be used for reconnaissances, in which the observations are made with great rapidity and therefore as a rule with less precision.

As to the accuracy attainable: in regard to the plan; admitting an error of $\frac{1}{250}$ of an inch in the observation with a magnifying-glass of points on prints, this on a circumference of 20-inch radius (corresponding to a focal distance of 20 inches) represents an angle of about 45″, and the maximum error in the location of a point 2700 yards distant would therefore be but 20 inches, which, reduced to the scale of $\frac{1}{5000}$, would of course be inappreciable. For the heights; assuming a point 1000 yards distant and the same focal distance, the error would be $\frac{36000 \times .004}{20} = 7.2$ inches, which corresponds to an angular error of about 30″, and, in observing with ordinary instruments, this degree of accuracy would seldom be excelled.

The facts set forth in this paragraph are results of the observations made at a time when photographic instruments were in a less perfect condition than at present. In the author's experience during the past year, in the outline photographic survey of a tract of about 12 square miles, using the camera represented in Fig. 9, a Dallmeyer rapid rectilinear objective, with $OP = 15''.68$, and plotting from the negatives with the aid of the tangent-glass, points of the plan checked exactly and in plotting the levelling, the difference in heights of points at various distances corresponded to the measurements made by careful work with a surveyor's level. The scale of the plot in this case was $\frac{1}{10000}$, and the field-work for the entire tract required but half a day.

It may be said that the accuracy attainable is sufficient for all ordinary purposes.

34. *Explanation of Plate I,—a Photographic Map* (*see end of book*).—Plate I (Plate XXIV, in "Topographical Drawing and Sketching"), from the Mémorial de l'Officier du Génie, represents a photographic map of an area of 4500 hectares,—in English units the rectangle is about 3.1 × 4.4 miles. The field-work was first plotted to the scale of $\frac{1}{5000}$, and afterwards reduced by photo-lithography to its present scale, $\frac{1}{30000}$. The small triangles, △, mark the vertices of the triangulation; these and the other points marked by a small circle, ⊙, are the photographic stations,—the minor triangulation, or traversing, by which the ⊙s were fixed, is omitted. The base was measured in the valley E. of Sainte-Marie-aux-Mines, and served, as shown, to fix points 1 and 2, and the directions of points 4, 5, 16 and 17: the side 1–2 was then used to fix the points 3, 4, 10, ... The contours have an equidistance of 5 metres; the field-work occupied 10 days; the number of photographic stations was 31; of prints, 52; and of points determined, 1400. This survey was conducted by M. Javary in 1869.

SECTION III.

CYLINDRIC PERSPECTIVES.—INSTRUMENTS, FIELD-WORK AND PLOTTING.

35. *The Topographic Cylindrograph.*—This ingenious instrument, a type of the cylindro-perspective class of cameras, is the recent invention of M. Moëssard, formerly professor of topography at St. Cyr, now commandant of engineers and professor "à l'École Supérieure de Guerre."

Views obtained with it are cylindric perspectives; the radius,—the focal distance,—is a constant quantity for vertical as well as horizontal angles; and the number of views required for a complete tour of the horizon is but two and a fraction (20°). Fig. 35 is a general view of the apparatus.

36. *The Camera.*—The camera consists of a semicircular wooden lid *A*, Fig. 36, and base *B*, which are horizontally disposed: and a vertical, rectangular, wooden frame *F*. These pieces are fastened together with hinges and hooks as shown, so that they may be readily folded for transportation. When opened, a brass standard *s*, attached to the lid in rear, rests upon the base, where it is fastened in position by a button, and thus serves to keep these parts rigidly parallel; this may also be folded against the lid for transportation. Strips *b*, of brass, project vertically 0.4 of an inch beyond the edges. The projections, *e*, Fig. 37, on the upper surface of the base, are guards or guides for the flexible plate-holder (see Fig. 40), which, when in position for an exposure, forms the cylindrical part of the camera. Projecting pieces, *l* and *c*, in rear of the base, serve as supports for the circular level, and for the compass, which is graduated from 0° to 360° in the usual direction, N., E., S. and W., and which has its 0°–180° line parallel to the middle radius of the lid, with the 0° point to the front. In the latest form of the instrument, two tube levels at right angles, and the compass, 4.7 inches in diameter, are let into the

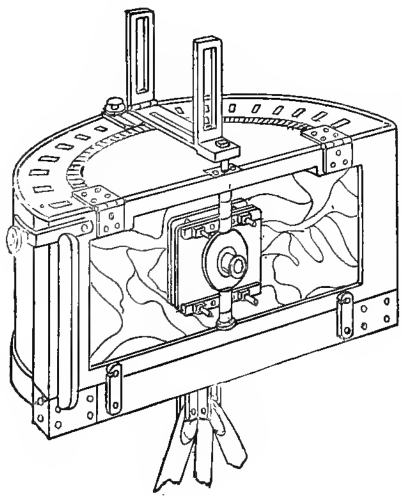

FIG. 35

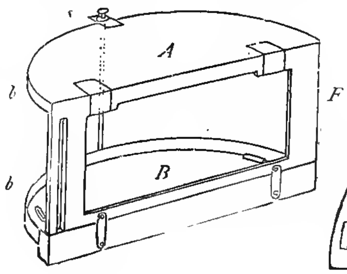

FIG. 36.

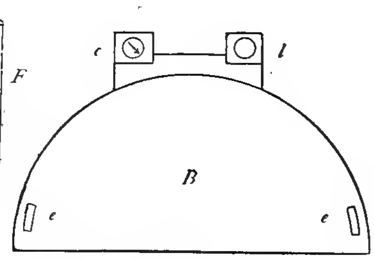

FIG. 37.

upper surface of the lid. A plate in the lower surface of the base serves to attach the camera to the tripod-head.

37. *The Objective.*—The objective-carrier, shown in Fig. 38, is so attached by a vertical spindle to the middle of the frame *F* (Fig. 36), that the optic axis of the objective is horizontal and the optic centre, or, in the case of a single lens, the rear nodal point, is in the axis of the camera. Fig. 38 shows the arrangement; the objective *o* is rigidly fastened to the rear plate *p*, and enters freely an opening in the front plate *f*, the plates being held together by adjusting screws and spiral springs as shown. Fig. 35 shows the manner in which the objective may be made to revolve horizontally,—the alidade, attached to the upper rectangular extremity of the spindle *t* (Fig. 38), serving as a handle. The other extremity of the alidade traverses a circular scale of degrees, which is attached to or engraved upon the lid, and which has its centre in the axis of rotation; the alidade is also furnished with a spring of slight tension, a click, projecting beneath and engaging in notches (Fig. 35) cut in the lid; which device serves to regulate the rate of motion of the alidade, by assigning so many clicks per second, and thereby to time the exposure. In front, light is excluded from the interior of the camera by a rubber cloth, attached to the rear plate of the objective and the inner edges of the vertical frame, and of such dimensions as to permit perfect freedom of motion to the objective.

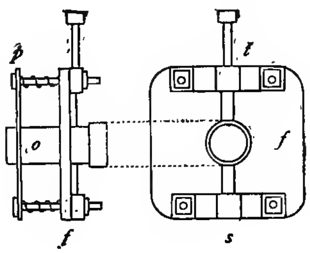

FIG. 38.

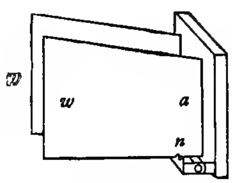

FIG. 39.

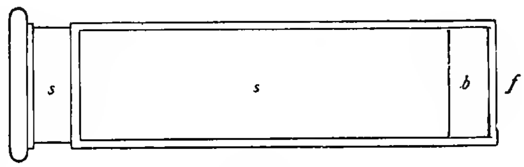

FIG. 40.

To confine the deviated rays to the area effectively covered by the objective, there are two wings or screens, *w*, Fig. 39, of tin blackened, attached to the rear plate of the objective-carrier and projecting into the camera; each turns freely about a vertical axis *a*, and, by means of the notches *n* in the rear projecting piece, may be made to occupy three different positions, thus increasing or diminishing the breadth of field: the projecting piece and screens may be folded against the plate for transportation. The screens should be of such size as to turn freely in the camera during the rotation of the objective. The folding vanes (Fig. 35) with cross-hairs, attached to the alidade, serve to determine at any instant that portion of the landscape which is being "taken" when the screens are parallel.

Any rectilinear objective, composed of either a single or double combination lens, will serve, provided its focal distance is equal to or a very little less than the radius of the camera.

38. *The Plate-holder.*—The plate-holder, Fig. 40, is a rectangular frame, *f*, of some solid, flexible material, backed with rubber cloth, *b*, stretched upon and glued to the frame,—the sensitized paper, which is used instead of glass plates, when in position, resting against it.

The shield *s*, of flexible card-board blackened, fits into grooves in the edges of the holder, and is manipulated in the usual manner. The milled head, shown at the left in Fig. 35, serves to release a hinged brass clamp, or cleat, when the holder is to be inserted, and to secure the holder after insertion, so as to entirely exclude the light. Several plate-holders are used, and are easily packed for transportation.

39. *Scale of Azimuths and Slopes.*—Fig. 41 represents the means by which a scale of azimuths and of slopes is impressed or marked upon the negative. Two notched, curved brass strips, *h*, having their centres in the axis of rotation, are attached vertically to the lid and base respectively, and immediately in front of the plate-holder; they project slightly beyond the frame of the latter, so that the notches may be represented on the negative by the exposure. The strips *v* are similarly attached to the edges of the vertical frame. The notches in *h* correspond to divisions of 1 "grade," or of 1°, as the case may be, to a radius = the distance from the plate-holder to the axis of rotation of the objective; and the notches in *v*, to $\frac{1}{100}$ part of this distance. Projecting points at *p* mark the horizon, or *HH'*. (*Note.*—On account of the blurred images thus produced, it would seem better to attach these strips made of very thin metal to the inner edges of the holder, so that during exposure they would rest in contact with the paper.)

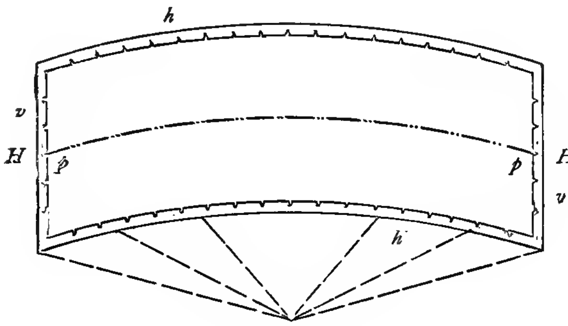

FIG. 41.

40. *Adjustment of the Optic Centre.*—In order that the image of every point should be clearly defined and immovable during rotation of the objective, it is necessary that the optic centre should be in the axis of rotation, in or near which line it is supposed to have been originally fixed by the instrument-maker. To test this condition: a narrow plate of ground-glass, ruled with fine vertical lines, is placed in the usual manner to receive the image of a distant point; if the image is displaced in the direction of the rotation, the rear plate of the objective-carrier must be advanced by means of the adjusting screws; if in a contrary direction, the plate is moved to the rear. In this adjustment, to preserve the parallelism of the plates, it is necessary that the screws should be turned equally, which condition is assured by means of indices on the screw-heads.

41. *The Manipulation.*—To make an exposure: the camera, with objective capped, is set up and approximately levelled; the lid is raised; the plate-holder, containing the sensitized paper, is inserted and clamped; the screens are favorably disposed, and the lid is closed. The camera is then levelled; the alidade is adjusted to the 85° division of the scale; the vanes are raised, and, by revolving the camera, the vertical cross-hairs are aligned upon the object to occupy the centre of the view. The shield is then withdrawn; the alidade is adjusted to the 0° of the scale; the objective is uncapped and revolved by means of the alidade, until the latter has reached the 180° division,—the velocity of rotation being determined as in ordinary landscape photography; and the cap and shield are then replaced. The time of exposure is also determined in some degree by the positions of the screens, being shorter when these are placed in the outer notches (Fig. 39).

42. *Device for Orienting the Views.*—A semicircular limb, having its centre in the axis of rotation and its radius less than that of the camera, is attached to the upper surface of the base, and is graduated into degrees or parts thereof, from 90° to 270°, corresponding in position to those on half the compass-limb. Two blocks are made to slide along this limb, each carrying a vertical spindle about $1\frac{1}{4}$ inches in length; one spindle is terminated at its upper extremity by an arrow-head, and the other by a crescent. Just before closing the lid for an exposure, one of these spindles is adjusted to the division corresponding to that marked by the compass-needle; and the other, to the division differing from it by 90°. By this obstruction of the deviated rays, their positions are marked upon the negative, the arrow-head indicating the N. or S. point, and the crescent the E. or W. point, thus furnishing the basis for the scale of azimuths. The division indicated by the compass-needle is also recorded in the note-book.

To illustrate: For the first exposure (see Fig. 42), the compass indication is 55°; the

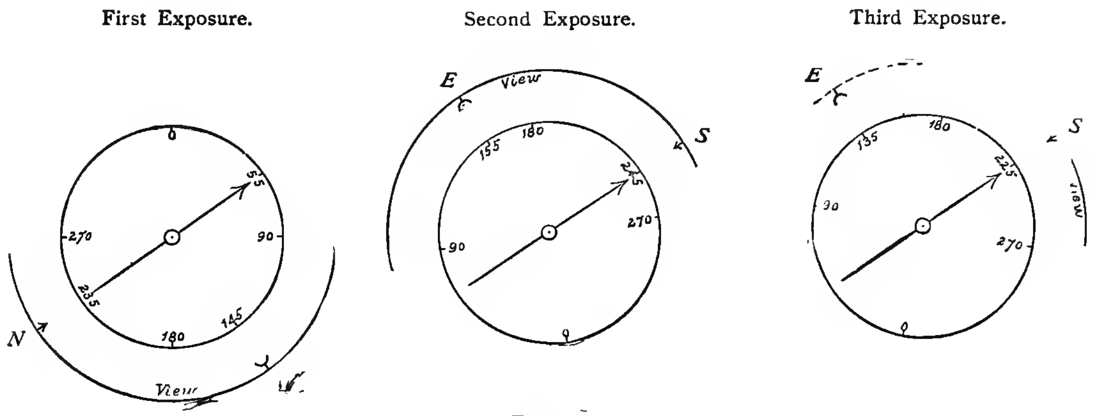

FIG. 42.

0°–180° line being parallel to the optic axis, with the 0° to the front, the direction of the middle point of the view is N. 55° W.; consequently to mark the N. point, the arrow-head is adjusted to the $55° + 180° = 235°$ division, and the crescent to the $235° - 90° = 145°$ division of the scale to mark the W. point. For the second exposure; the field being 170°, and the order in which the views are taken being from left to right: when the camera is revolved 170°, the compass indication is 245°; the arrow-head is adjusted to this division and will mark the S. point on the negative, while the crescent, at the $245° - 90° = 155°$ division, marks the E. point. The two views cover $170° \times 2 = 340°$; a third view of 20° is therefore required to complete a tour of the horizon. The exact supplement is obtained by revolving the camera until the needle indicates $245° - 20° = 225°$, when the adjusted arrow-head will mark the S. point; and by withdrawing the shield a sufficient extent, the E. point may be marked by the crescent placed at $225° - 90° = 135°$. For reasons heretofore given, it is advisable to have the views overlap, say 10°, in which case the arcs of revolution of the camera would be correspondingly diminished. (*Note.*—The additions and subtractions above required could in great measure be avoided by reversing the order of the numbers on the base scale.)

43. *The Field-work and Plotting.*—The *field-work* corresponds in detail to that de-

scribed in paragraphs 18 to 23 for plane-perspective cameras; any exceptions due to the form of the instrument readily suggesting themselves.

Fig. 43 represents a print ready for *plotting*. HH' is the horizon; SS' and WW' are verticals drawn through the S. and W. points respectively; and z is the azimuth of a point o, 65° from S., or 115° from N.,—S. being usually taken as the origin. The vertical angle of o is read off, as a slope-angle, on the side scale; and is $\frac{1}{100}$, . . $\frac{3}{100}$, $\frac{4}{100}$, . . ., according to the number of divisions from H' to h'.

In measuring the azimuths, use the mean of the distances SZ and $S'Z'$; and similarly for the vertical angles, use the mean of Hh and $H'h'$.

The stations plotted, a circle is described with each plotted station as a centre, and with any convenient radius; the azimuths of the different points, determined as above, are protracted, and the points are located on the plot by intersections of right lines drawn

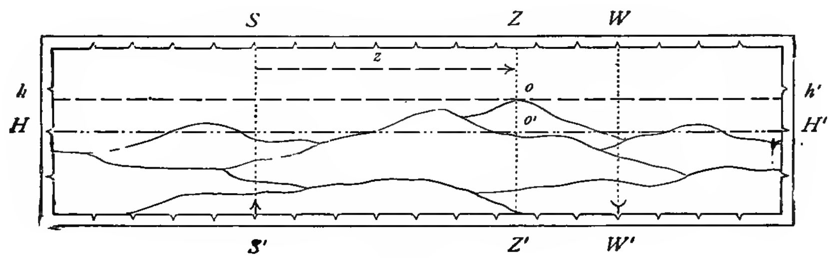

FIG. 43.

from the plotted stations through the corresponding azimuthal divisions. It is apparent that when chords, sines, tangents, or ordinary protractors are used in protracting the azimuths, the greater their radii the more accurate graphically will be the results.

As to the heights; the reference of any point is given by means of the side scale, e.g.: Suppose $\frac{H'h' + Hh}{2} = 3.5$ divisions; then, the reference required is $.035 \times$ the plotted horizontal distance from the station to the point.

44. The *advantages claimed* in the use of this instrument are:

I. Since the scales are already impressed in the exposure, measurements may be made directly upon either the negative or print; the only construction required being that of the right lines, as hh' and ZZ' (Fig. 43), through the images of the required points; but on account of distortions, which might take place in printing, it is advisable to draw these lines on the negatives.

II. No construction of the focal distance is required; nor is it necessary to consider it in the field-work, because the apparatus is effective only when the optic centre is in the axis of rotation; and, when adjusted, the focal distance is exactly equal to the radius of the cylinder.

III. No distortion exists if the objective is rectilinear, owing to the screens limiting the field to that effectively covered by the lens; if it does exist, the images will not be clearly defined, therefore when these are clearly defined there is positively no distortion. In vertical planes, however, there may be a slight distortion near the edges of the field; but this is of slight importance, since the higher points are in the sky portion of the

view, and the lower points are so near the station that any small error in a corresponding slope-angle may be neglected.

IV. Eccentricity of position in the plates during the exposures 1, 2 and 3 at any station presents no inconvenience, because each view is oriented independently of the others, on the cardinal points; and, when required, the compass-readings, which are always recorded, furnish the elements necessary to orient the three views at the plotted station. The three-point problem may also be utilized in locating a station on the plot. (See also close of par. 52.)

To give the photographic view a natural appearance, or to represent the details as they would appear at the station, the "cylindroscope" may be used. It is simply a wooden semi-cylinder, of dimensions equal to those of the cylindrical part of the camera; the photographs are placed on its interior surface and observed from the middle point of its axis.

SECTION IV.

RADIAL PERSPECTIVES.—INSTRUMENTS, FIELD-WORK AND PLOTTING.

45. *Photographic Plane-tables.*—If at any station a photographic view of the surrounding tract be represented upon a horizontal surface, every point of the representation occupying its true position; then will the horizontal angle of any two points be measured by the angle included by the right lines, or radii, drawn from the plotted station through the images of these points. This is the principle of construction of the following-described instruments. As to relative heights of points, means for their determination similar to those described for plane and cylindric perspectives are employed.

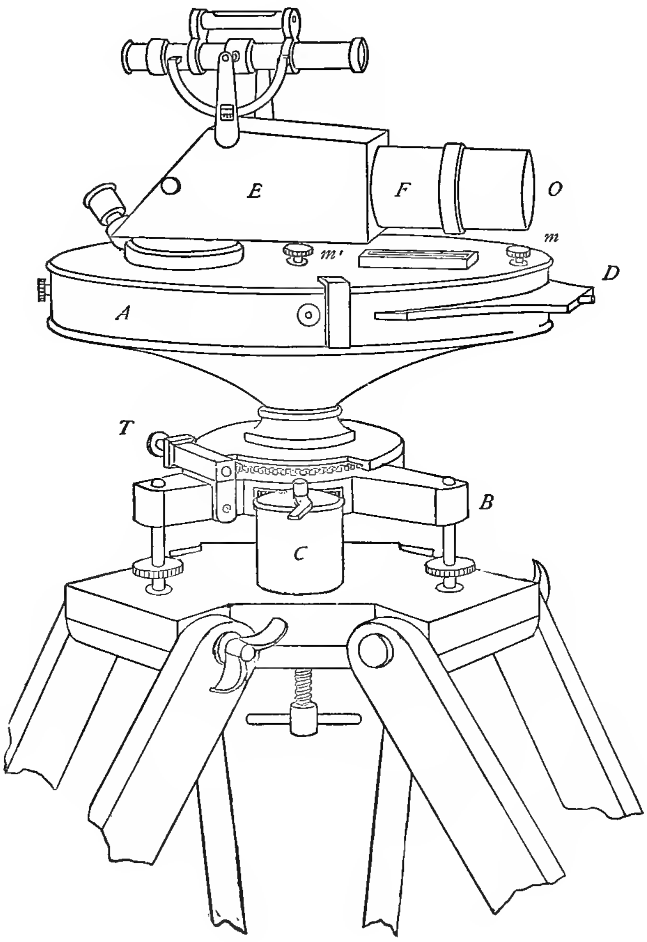

FIG. 44.

46. *Chevallier's Camera.*—In 1858, this instrument was submitted by M. Auguste Chevallier to the consideration of the "Société d'Encouragement," and favorably received; and since that date the inventor has succeeded in bringing it to a still higher state of perfection. In its present improved form, and as manufactured by the optician Duboscq of Paris, it consists of a circular dark-chamber, *A*, Fig. 44, resting upon a triangular support, *B*, which is furnished with levelling-screws that bear upon the tripod-head, as shown. These attachments are similar in construction to those of a theodolite, thus admitting of a revolution of the chamber in azimuth,—a tangent-screw, *T*, serving for close adjustments. A plate-holder, *D*, shown inserted, contains the sensitive plate. The cover, or upper plate of the chamber, which carries the objective system, is movable about its centre, its edge resting in double grooves in the upper edge of the cylindrical rim; its serrated edge is geared to two pinions, which may be engaged at pleasure; to one of these pinions motion

may be communicated by means of a simple clock-work movement, C, thus ensuring uniform rotation; while the other, furnished with a projecting milled head, m, serves to revolve the plate by hand to any desired position. A graduated circle is fastened to the edge of the chamber immediately below the edge of the plate, and diametrically opposite openings in the latter permit the reading of arcs or angles. A small circular level serves to ensure the horizontality of the plate; at the centre of rotation and projecting through the milled head m', is a sharp metal point, furnished with a spiral spring, which is thrust downward to mark this centre on the sensitive plate,—an operation, however, which may be dispensed with, as will be shown; m' also serves another purpose, to be described.

The objective system consists of the box E and tube F, the axis of the latter and that of the dark-chamber being in the same plane; the tube contains the lens, and the box has at its rear extremity a triangular glass prism, with its edges horizontally disposed. Rays from external objects entering the tube at O are, after deviation by the lens, reflected vertically downwards through a circular opening in the plate, and are focussed on the sensitive plate; this opening, as shown in the figure, being between the centre and edge of the plate.

A circular disk with sectoral openings of different dimensions is suspended immediately above the sensitive plate, its centre being in the axis of rotation of the instrument; and, by means of indices on the milled head m', any desired sector may be brought beneath the opening through which the reflected rays pass, thus limiting the field and preventing it from extending beyond the centre of rotation. Thus, in Fig. 45, X is the axis of rotation of the instrument, l and P the lens and prism respectively, r the sensitive plate, and S the screen,—S' representing the latter in horizontal projection, and with different sectoral openings. h and h' are cross-hairs, which by their obstruction of the light are represented upon the negative; h is coincident with a radius of the screen; and h' is perpendicular to h at the point in which the ray, coincident with the optic axis of the lens, intersects it after reflection by the prism: therefore, when operating by "fixed sectors" (par. 47), all points, of which the images are located on h', are on a level with the optic axis at the station where the exposure is made. Simply to mark the trace of the "principal plane,"—that containing the axes of rotation and of the objective,—the smaller sectors are used; and the smallest, about 1°, in operating by "continuous movement" (par. 48), in which case h is suppressed.

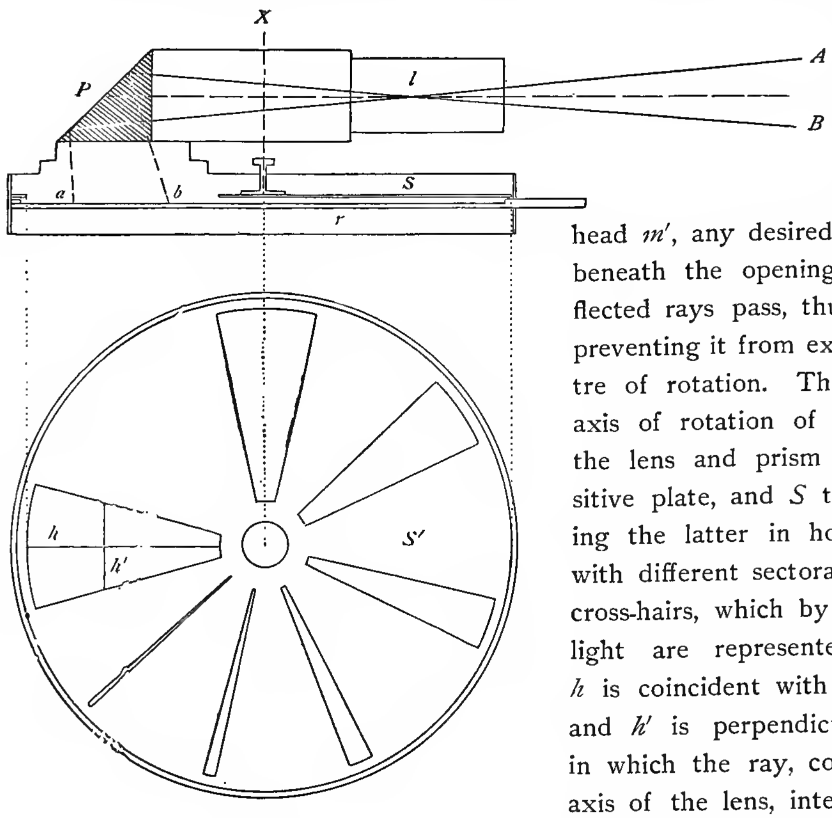

FIG. 45.

It is apparent that to facilitate plotting, the distance of the image of h' from the centre of rotation of the sensitive plate, should be exactly equal to the focal distance of the objective, and this condition is assured by the instrument-maker.

In addition to the parts above enumerated, a small telescope with cross-hairs, and a vertical limb, are attached, as shown, to the upper surface of the box; and are used for pointing, and to measure vertical angles of points that may lie without the field of the objective,—the latter case however rarely occurring. When the instrument is set up, the optic axes of the telescope and of the camera-objective are in the same vertical plane. An attached compass affords the means for orienting the views in the subsequent plotting, and two methods for this purpose are prescribed;—one consists in rotating the plate, after an exposure is made, until a covered slit in the base of the compass-box, and which extends through the plate, is in the vertical plane of the needle; this cover is then removed for an instant, and an image of the needle is formed on the sensitive plate, thus giving the required meridian line: as the compass is located near the edge of the plate, the image of the needle will not interfere with other details. The other method consists in placing a staff vertical at some distance in front, and in the field of view; its image in the negative, and its bearing obtained by means of telescope and compass, afford the necessary data. The instrument is permanently focussed by the maker for distant views; and the usual form of cap is used in making exposures. In regard to size, it may be stated that excellent work has been done with a camera constructed for sensitive plates affording circles of but 4 inches in diameter.

47. *Operating by Fixed Sectors.*—This is its least important use. Suppose the camera set up at any station, pointed at a distant signal, and an exposure made; an image of the signal and its surrounding features is obtained, and the image of h will cut that of the signal. If now the plate be rotated, the chamber being clamped, and an exposure made toward a second signal, it is evident that the angle included by the two images of h on the developed negative, is the true horizontal angle of these signals as measured at the station. The image of h' will in each view intersect points of all objects having the same altitude as the optic axis. By using a sectoral opening of about 10°, a view is obtained in which the maximum error due to distortion falls within the limit permissible in the graphical construction of a plan. It is unnecessary to point exactly at any signal, because with rough pointing the image will always be found in the vicinity of h, and all the images of h in the different sectors must have their true relative positions; and in this property rests the value of the instrument for rapid work.

48. *Operating by Continuous Movement.*—In this mode of working lie the great advantages derived from its use, viz.: absolute accuracy in the measurement of horizontal angles, and the great rapidity with which the field-work may be performed.

In the preceding operation, a narrow sector had to be used to avoid distortion, and to complete a tour of the horizon many views were required. If with this sector a continuous movement were given to the plate, sector and plate revolving together, images of objects would be superposed and become indistinguishable; but by reducing it to a very narrow slit, coincident in position with h, the sensitive plate will receive at each instant the images of those points only that are situated in the principal plane (par. 46); there will be no superposition throughout a revolution; and, from a view thus obtained, the true horizontal angle of any two points is given by the radials that intersect the images of these points.

If, in reference to the required plan, certain sectors of the landscape are unimportant, it is only necessary to cap the objective while traversing them: but with the rapid plates now in use, no appreciable time is lost by making the entire tour.

As already stated, the cross-hair h is suppressed, while h', reduced in length practically to a point, leaves its image upon the sensitive plate in the form of a circumference of a circle, described with the centre of rotation as a centre, thus indicating the true horizon of the station.

It is apparent that with an inverting objective, and the relative positions of objective and prism shown in Fig. 45, the sky will occupy the outer portion of the picture. Such a representation is called "nadiral," in contradistinction to one in which the sky

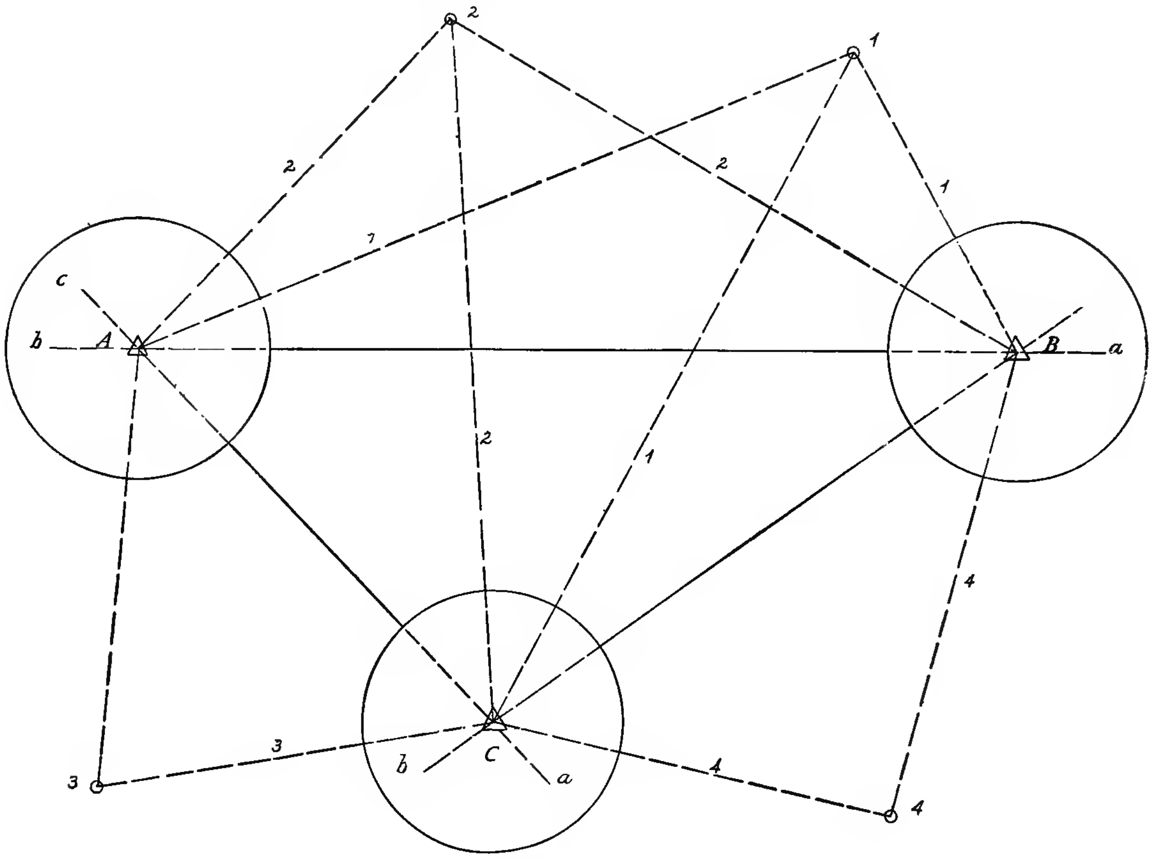

FIG. 46.

occupies a central position, which is termed "zenithal:" the latter is evidently produced by placing the inverting objective between the prism and sensitive plate, as in the other form of this instrument. Although these representations possess the same value for surveying purposes, the former presents the more natural appearance. In either case, a radial drawn upon the sensitive plate represents the vertical of any point, the image of which it intersects.

49. *The Field-work and Construction of the Plan.*—As in other methods of surveying, a base, as AB, Fig. 46, is measured, and from each extremity a tour of the horizon is made; this is repeated at a third station, as C, which is contained in views from A and B; and so on throughout the tract. The selection of stations is governed by the conditions

already stated in par. 19. It is apparent, from the usual multiplication of representations of any point, that numerous opportunities for verification are afforded for the plotting. It is hardly necessary to state that, in setting up the instrument, the centre of rotation should be plumbed over the station-point, and the axis of rotation made truly vertical.

In constructing the plan, either negatives or prints may be used directly as protractors. On the negatives, the landscape is represented as if rotated horizontally 180°; due allowance should therefore be made for the position of the N. point. On the prints, in addition to this, when the sensitive plate is exposed film up, the positions of objects are reversed; and the remedy lies in either placing the film down, or in making the prints transparent with oil or other material.

Fig. 46 fully illustrates the construction of the plan; the base is plotted to the required scale; the views from the extremities are placed with their centres at these plotted points, and are rotated until their meridian lines are parallel to the direction assumed for the meridian upon the sheet; right lines are then drawn from the centres to corresponding points and produced to intersection, thus locating required points as in plane-table surveying. A third view is then similarly oriented and used, and so on throughout the work.

50. *Determination of the Heights.*—Since the image of the circumference described by the cross-hair h' is the horizon of the picture, it serves as a datum line to which all points are referred: the *reference* of any point is therefore given by the formula

$$x = md\frac{h}{f};$$

in which f is the focal distance, $\frac{1}{m}$ the scale of the map, d the distance from the station to the point, measured on the plan, and h the vertical distance of the point from the horizon, measured on the view. Since the maps, or at least the first sheets of the respective maps, may all be plotted to the same scale, $\frac{m}{f}$ may be considered as a constant quantity; a convenient coordinate table may therefore be prepared, giving the values of x for values of d and h, differing by, say, 100 feet and 10 feet respectively, thus facilitating the plotting. The references to a common datum plane are obtained in the usual manner.

51. *Instrumental Error, Advantages Claimed.*—The *errors* are those observed in all optical instruments employing lenses. Distortions in a horizontal direction are destroyed; while those in a vertical direction, if existing, may be detected by comparison of "fixed sector" views with those obtained by "continuous movement," and then corrected. The only cause of confusion is the slight angular deviation of a vertical ray after passing through a small sector, thus causing it to spread to the right and left of its true position a distance equal to half the breadth of the sector; but this lack of definition is obviated by using a sectoral opening not greater than 1°.

As illustrating its accuracy, M. Jouart states that, in his own practice with an instrument of this kind having a focal distance of 7.5 inches, and in plotting to a scale of $\frac{1}{5000}$, satisfactory results were obtained up to distances exceeding 1 mile. In a recent Parisian publication, M. Gossin also states that its use is attended with excellent results.

The range of the instrument evidently depends entirely upon the power of the objective used.

The main *advantages claimed* for it, as compared with ordinary surveying instruments, are the certainty with which a tour may be closed, and errors of arc-reading thus obviated; the great rapidity of execution; its simplicity of manipulation, which enables a novice to produce practically perfect views; and, as with all photographic surveying instruments, the production of complete views of the topographical features. Captain Hannot, chief of the photographic service of the Belgian war department, states, in regard to this instrument, that in its construction it embodies in a most happy manner all the improvements of which a camera is capable; and that, as compared with the ordinary plane-table, it possesses a great number of advantages in its favor. With the very sensitive dry plates now generally available, and the very narrow sectoral opening made permissible by their use, joined to careful construction and the employment of a good objective, this instrument must prove of valuable assistance in surveying, for both civil and military purposes.

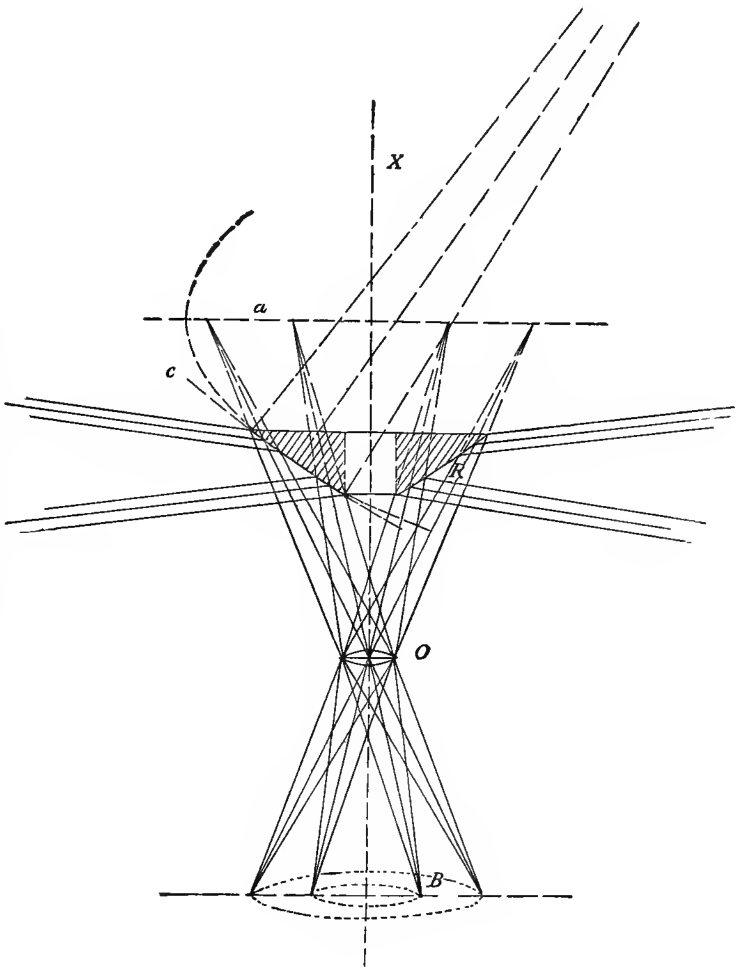

FIG. 47.

52. *Mangin's Camera.*—This instrument, like that just described, is of French invention. It produces, without rotation of any part, an entire tour of the horizon upon a single plate. The theory of its construction is based upon the idea—due to Capt. Prudent—that virtual images produced by a spherical convex reflector, might be photographed so as to represent the original objects in their true proportions.

I. *The Metallic Reflector.*—Col. Mangin solved the problem, by first constructing a reflector of which the form of the generating curve was dependent upon the condition that the virtual images should be rigorously exact for its median zone. This reflector, *R*, Fig. 47, is a silver-coated surface of revolution, having its axis, *X*, vertical, in order that it may receive the incident rays from all points of the horizon. By total reflection, the pencils are made to converge to a point, *O*, of this axis; where an objective, having its

optic axis coincident with that of the reflector, serves to produce upon the sensitive plate placed on the base, *B*, of the chamber, the conjugate of an image formed by the reflector.

For photographic purposes, each point of the virtual image should be true and clearly defined, and the pencil of rays emanating from it rigorously conical, in order to produce on *B* a true image of the original point. Neither a spherical nor a conical reflector would serve this purpose, when the incident and reflected rays make considerable angles with each other; but, by making the generatrix an arc of a parabola, with its axis, *a*, horizontal, the incident rays in the horizon of the station are reflected to *O* as desired. In the manufacture of the reflector, the arc, *c*, of an osculatory circle, tangent at the middle point

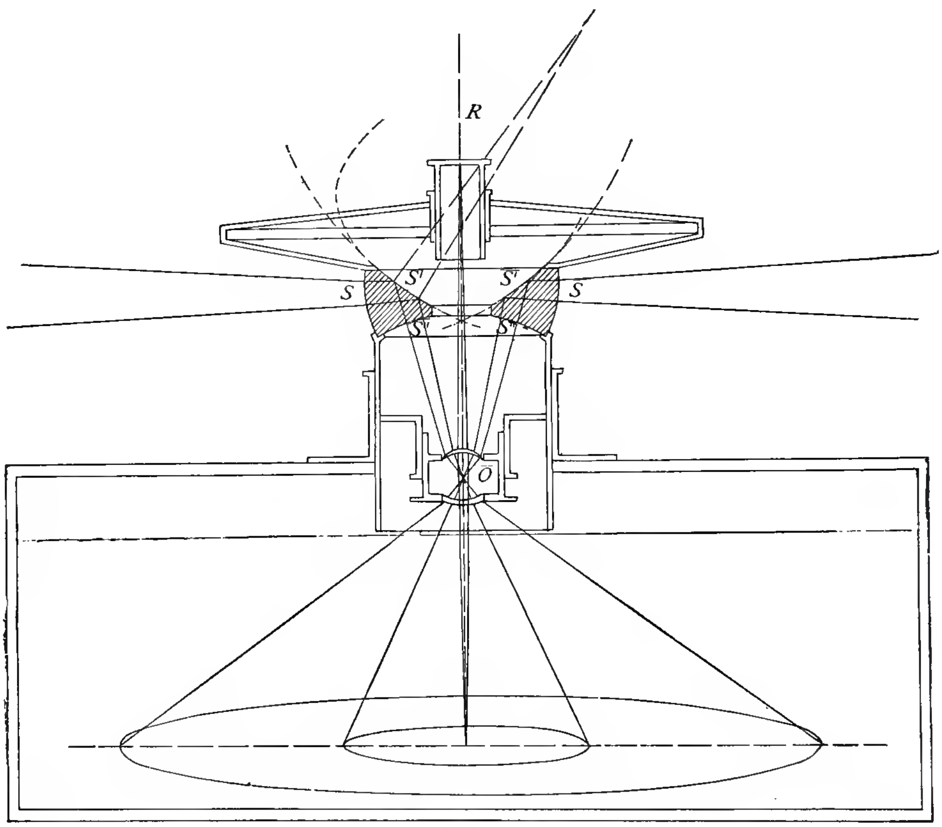

FIG. 48.

of the parabolic arc, was substituted for the latter, and the construction is allied to that of the annular light-house lens.

As the distance, measured on the reflector, from the median zone, or middle horizontal circle, increases, the definition decreases; but it is found by experiment that rays, incident upon any part, which make angles of 15° with the horizon, are sufficiently well defined for practical purposes; the vertical field of the instrument is therefore 30°.

The distance from *O* to *B*, and the selection of an objective to place at *O*, are governed by the rules observed in making enlargements by photography. For example: Let *d* denote the distance from *O* to the median plane of the reflector; then, to produce on

B an image twice the diameter of the virtual image; OB must be equal to $2d$, and an objective is used of which the focal distance f is derived from the expression $\frac{1}{f} = \frac{1}{d} + \frac{1}{2d}$.

II. *The Glass Reflector.*—The metallic reflector is easily tarnished by chemical reaction, and is therefore hardly suited to photographic work; to remedy this, Col. Mangin constructed one of glass, of which the form is such as to correct the effect of refraction. The outer surface, S, Fig. 48, which receives the incident rays, is torus-shaped; the upper or reflecting surface, S', is of the same form as the metallic reflector; and the lower surface, S'', is spherical, its centre, O, being the focus of the reflected rays: the objective at O is for the purpose described in (I). This reflector has another advantage, since reflected rays are not obstructed by the mountings which are required for the metallic reflector.

With this camera, the diedral angles formed by vertical planes intersecting the station and exterior points, are truly represented on the picture by the sectors included by radials drawn to the images of the points,—the centre being the image of a minute opening, which admits the vertical ray R in the axis of the reflector; and all points, in any vertical plane of the station, have their images in the same radius. The horizon of the picture, HH', may be defined, either by the image of a circumference engraved on the reflector, and which is concident with the line of contact of a vertical cylinder; or independently, in which case any distant point in the horizon of the station is noted, and, with the axial point as a centre, a circumference passing through the image of this point is then described on the negative or print,—checks are afforded by observing two or more points.

The operation of *plotting*, from the negatives or prints, is evidently similar to that described for Chevallier's camera.

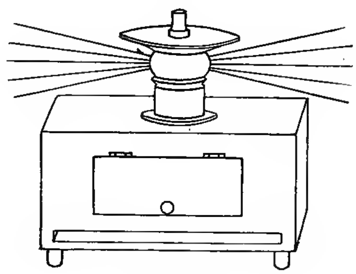

FIG. 49.

Fig. 49 represents the camera complete. In another form of this instrument, a triangular prism is employed to reflect the rays, after deviation by the objective, to the sensitive plate vertically disposed,—this arrangement making the camera more compact.

SECTION V.

THE CAMERA WITHOUT A LENS.

53. It is well known that, if rays of light from exterior objects enter a dark chamber through a very small aperture in one of its sides, images of these objects are formed on the side opposite the aperture, and that the images will be sharply defined if the aperture is circular and its edge is free from flaws.

The apparatus required is either an ordinary camera, or a box especially constructed for the purpose. For general purposes its length when extended should be at least 12 inches, and its lateral dimensions such as to admit an ordinary plate-holder containing plates of the required size. Means already described are resorted to for the setting up and levelling. The position of the aperture should correspond in every respect to that of the intersection of the optic axis of an objective with the front face of a camera; therefore, to make the arrangement complete, the aperture should be constructed in an ordinary objective-slide, of which the centre, or flange for a lens-tube, is filled with some opaque material. Apertures of different sizes, corresponding to different fields of view and sizes of images, are required; it is therefore more convenient for manipulation to construct them as hereinafter described, and attach the plates to a single metal strip which may be held and moved in grooves against or across a central opening in the slide, so that any desired aperture may be readily made to face the opening; or a revolving disk containing the apertures may replace the strip. A superposed sliding strip, or another revolving disk, will serve as a cap in making exposures.

To admit oblique rays, either the aperture must be conical, or else constructed in very thin metal. In the former case, a conical cavity, of which the angle at the vertex should be at least 90°, is drilled nearly through the metal, and the perforation is completed with a needle-point; in the latter, the thin metal, platinum, tin-foil, or gold leaf, is placed on a flat, smooth, hard-wood surface and pierced with a needle, care being taken in this as in the former case to make the aperture circular and of the required size; the latter is easily determined with the aid of a magnifying-glass and a finely divided scale of equal parts,—a needle gauged and suitably marked will prove useful in this operation. When thin or leaf metal is used, it is of course attached to annular pieces of thicker, or less pliable material, before being fastened to the strip or disk; and the latter is suitably pierced so as not to obstruct the rays. As a precaution against reflections in the camera, metal parts facing the interior should be blackened.

To obtain well-defined images the sizes of apertures, and the distances from apertures to the sensitive plate, which may be termed *aperture distances*, should vary according to the following rules derived from experiment:

For an aperture distance of 3.14 inches, the size of aperture is 0.012 of an inch;
" " " 11.80 " , " " " 0.02 " " ;

and between these distances, the sizes vary proportionally from those given.

It is apparent from a consideration of the limiting rays of any field of view, or of any object, that the shorter the aperture distance, the wider will be the field embraced in a photograph, and the smaller will be the images. A short aperture distance entails less

exposure than a long one, because of the greater illumination; and a 90° field is found to be about the limit of equal illumination.

Assuming, for surveying purposes, 90° as the desired horizontal field or angle of view, then in order that any plate shall exactly contain the view, the aperture distance should be one half the horizontal dimensions of the plate; but for reasons heretofore stated a marginal allowance is advisable, therefore it is best to make the distance a trifle less—say 4.75 inches for an 8×10, and 3.75 inches for a 5×8.

In the use of this camera, images on a ground-glass are so faint as to be distinguished with difficulty, except in the brightest light; therefore, to dispose the camera for any view, the following simple device is employed: For the horizontal field; mark, by a projecting pin or otherwise, a point on the front upper edge of the camera and exactly in the vertical of the aperture; and mark two other points on the rear upper edge, one near and opposite to each extremity of the upper edge of the sensitive plate; then the prolongations of the sides of the angle, formed by joining the front point with the other two, will evidently serve, by sighting along them, to adjust the aperture distance so that any desired field will be contained by the plate. A similar device on a side of the camera serves to determine the vertical field.

A tour of the horizon requires but four separate views of 90° each; and each view may be limited to its proper quadrant as follows: At the first exposure, sight a distant point in the prolongation of one of the lateral faces of the camera; then, assuming the camera to be rectangular in plan, for the second disposition, revolve the camera until this point is intersected by the plane of a longitudinal face; and similarly for the two remaining views.

With sensitive dry plates, the period of exposure for landscapes is about 10 seconds in sunlight, and from 25 to 35 seconds on a cloudy day. With a Stanley dry plate, sensitiveness 25, aperture 0.013 of an inch in platinum leaf, aperture distance 4.5 inches, and exposure 10 seconds, the author obtained an excellent negative, which at ordinary visual range could hardly be distinguished from one sharply focussed with a lens. The following table from successful experiments will prove useful:

Subject.	Plate.	Aperture.	Ap. Distance.	Exposure.	Remarks.
		Inches.	Inches.		
Landscape......	Wet plate......	0.02	11.81	10′ to 15′	Cloudy weather.
"	Dry plates, sensitiveness 25..	0.12	3.14	10″	In sunlight.
"	" "	0.12	3.14	25″ to 35″	Cloudy weather.
In studio........	" "	0.02	12.0	1′	Subject 10 ft. distant, well lighted.

There are certain merits due to this method, viz.: that, when the camera is properly set up and levelled, the images formed are free from distortion, and it may be recommended for accuracy and simplicity. Its usefulness must of course be determined by local circumstances and conditions, such as the degree of definition required, sensitiveness of the plates, and the kind of lens available for other methods of working. The principle may be readily applied to the production of plane, cylindric, or radial perspectives.

SECTION VI.

TELESCOPIC AND BALLOON PHOTOGRAPHY.

54. *Telescopic or Long-range Photography.*—This has for an object the photographic representation of features beyond the range of the ordinary camera-objective. The means required consist of a telescope attached to the front of the camera, and which has its optic axis in the prolongation of that of the camera-objective;—the latter objective may be dispensed with. Fig. 50 shows an arrangement of camera and telescope for the purpose. Fig. 51 represents M. Lacombe's device for attaching the telescope; after inserting the eye-piece *a*, the tube-ring *b*, which has a thread cut on its projecting cylinder, is screwed into the outer extremity *c* of the objective-tube; a diaphragm, *d*,

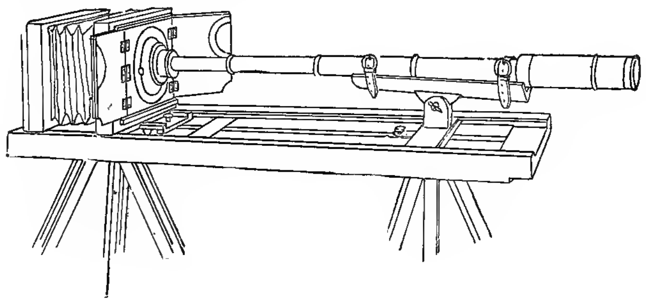

FIG. 50.

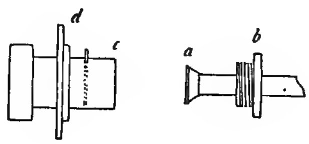

FIG. 51.

with large opening preventing the eye-piece from injuring the objective. Fig. 50 represents the other arrangements and the manner of focussing.

Another French operator, M. Mathieu, dispenses with the metal ring *b*, using instead a cylinder of stiff red cloth, which excludes actinic rays. While making the exposure, he envelopes the apparatus with a thick black cloth, in order to thoroughly exclude all light except that which enters through the telescope. There are two conditions indispensable to success: one, that all light, except that proceeding from the subject to be photographed, must be excluded from the apparatus; and the other, that the exposures must be timed with great care.

Figs. 52 and 53 are sketches from "La Nature" of M. Mathieu's work, the feature *C* in the former being magnified as shown in the latter, by the means just described. As to the details in this case: The camera used was a 5×7, and the lens a No. 2 Darlot. The time of exposure with an 0.08-inch stop, an ordinary dry plate, and a range of 0.75 mile, was 90 seconds. Good negatives were obtained at a distance of 3.75 miles.

This method is much like that practised in taking lunar photographs, and which is described in some astronomical treatises. Its application for surveying purposes would prove of value for representing inaccessible objects, such as the peaks and precipitous

slopes of mountains; and, in military operations, when the detailed description of a dis-

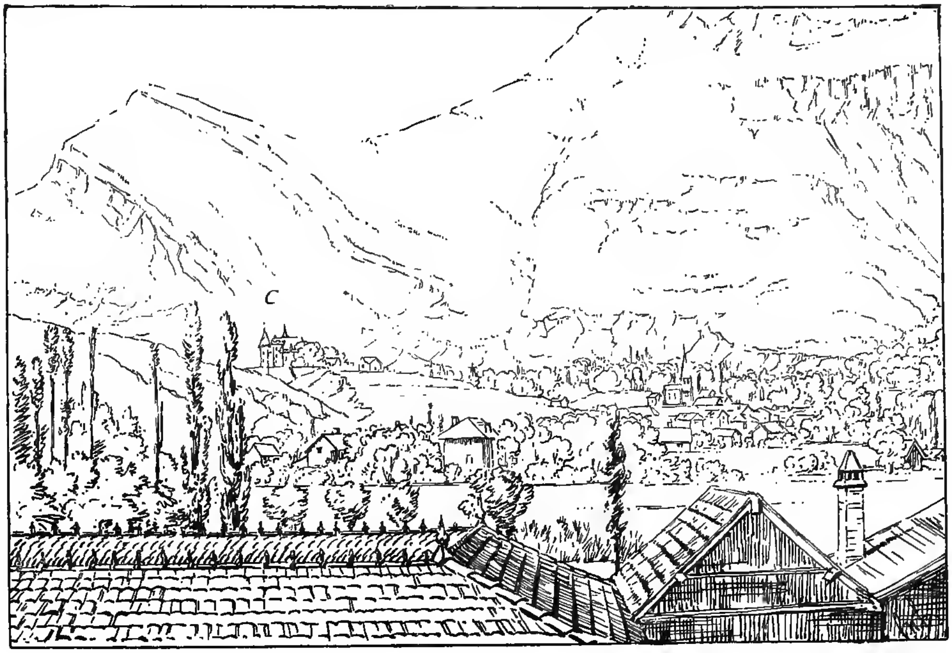

FIG. 52.

tant redoubt, or other fortification or position is needed.

55. *Balloon Photography—Sketch of Progress to* 1880.—Visual command afforded from great heights on a clear day is nowhere so perfectly attained, as from the cage or car of a balloon a few thousand feet above the earth's surface; there is no substructure to interfere, and the country is spread out like a map beneath. The idea of taking advantage of such favorable conditions for photographic surveying seems to have originated, in 1855, with M. Andraud; but it was not put into practical form until 1858, when M. Nadar, who, having no knowledge of a previous conception of the idea, resolved to do no less than make a survey of entire France, by means of photography and a captive balloon. His plan was to ascend to a height of 1000 metres above points previously determined; this height would command an area of 1,000,000 square metres, or 100 hectares (about 250 acres); and, since at least ten stations could be occupied daily, weather permitting, 1000 hectares would be the day's work. For military purposes, during a campaign, communication with headquarters was to be maintained by means of a box,

FIG. 53.

sliding along one of the cords which held the balloon, and by which the prints containing views of the enemy's position, etc., were to be dispatched every fifteen minutes. Patents were secured both in France and foreign countries, and he set to work developing his plan. The swaying of the balloon, lack of sufficiently rapid plates, and the escape of gas from the envelope, made the manipulation so difficult that the photographs obtained were of little value. Subsequently, however, in 1868, he succeeded in taking many useful balloon photographs which, considering the means then available, were as perfect as could be expected.

In the War of the Rebellion, captive balloons were frequently used to obtain information as to the surrounding country, the enemy's position, etc. In May, 1862, the Union army before Richmond employed one, and succeeded in photographing on a single plate all the country between Richmond and Manchester on the west, and the Chickahominy on the east; the rivers, smaller streams, railroads, marshes, pine-woods, etc., were all represented, as well as the dispositions of troops. Two prints were made from the negatives thus obtained; one of which was retained by the army commander, and the other by the aeronaut. Rectangles were ruled on them, the same number and disposition on each; reference-letters were attached; and, since in the subsequent ascents telegraphic communication was maintained between headquarters and the balloon, the prints enabled the aeronaut to give information of all important events that transpired in any rectangle; which information in several instances proved very valuable.

At this time, similar and successful use of balloons was made on the Mississippi near Cairo. These results, added to those attained during the war of 1866 in Bohemia, led to the formation in France of the French Society of Aerial Navigation, in existence at the present date, and including men of wealth and scientific attainment: the participation of its members in the Franco-Prussian War, particularly during the siege of Paris, when both free and captive balloons were employed, is well known. The faults of management and the failures that occasionally took place, and these were more especially noticeable on the German side, were mainly due to inexperience, imperfect apparatus and lack of instruction;—in this connection, it may be stated that the Germans, in 1887, added to their army an aeronautic section of fifty men.

The Meudon School of Aerostation was formed in 1871 for the purpose of instructing soldiers in the duties of aeronauts. A commission, of which Col. Laussedat was the most active member, was appointed the same date to study this subject, and it devoted especial attention to balloon photographic surveying.

In 1878, M. Dagron undertook to carry out the scheme proposed by M. Nadar; but the slow action of wet plates, joined to oscillations of the balloon, resulted in confused negatives; and it was only on a very calm day that he finally succeeded in obtaining a fair negative of part of the city of Paris, in which most of the prominent features could be recognized.

In the following year, dry plates and the instantaneous shutter were used by M. Triboulet; but after making an exposure in a free balloon at a favorable altitude of 500 metres, a storm caused a descent into the Seine, and custom-house officers opened his plate-holders to examine for contraband articles.

In 1879, on account of services rendered in Afghanistan and Zululand, the English

war department made ballooning apparatus part of their permanent military outfit, and provided for the instruction of troops in its use.

56. *Recent Experiments.*—In June, 1880, M. Desmarets, with rapid dry plates and an electric instantaneous shutter, obtained two good negatives. The first represented a portion of the village of Mésnil-Esnard near Rouen, including an area 900 metres square, to a scale of about $\frac{1}{4000}$; the altitude of the balloon was about 1100 metres, the velocity of ascent 6 to 8 metres, and the weather misty. Although lacking in clearness, buildings, roads, trees, and piles of stones intended for paving purposes, were defined. The camera was so disposed that the objective-tube projected through an opening in the base of the car. The other negative was made at an altitude of 1300 metres, and embraced the country between Rouen and Quillebœuf; unfortunately clouds intervened in many places; but, by an enlargement of the original, M. Carette unexpectedly brought out many details, which before were unobservable with a microscope. In the second operation, the camera was secured to the side of the car, altitudes were measured with a very sensitive aneroid barometer, and the objective used was a Derogy 8×10, with a focal distance of 11.5 inches; and, since the time of exposure was about $\frac{1}{20}$ of a second, and the velocity of translation of the balloon about 6 to 7 metres per second, the angle of displacement —about 8″—was insensible. This experiment attracted much attention and therefore gave the subject greater prominence.

In 1883, Mr. Shadbolt of England succeeded in making with dry plates good negatives from exposures at altitudes varying from 500 to 1000 metres. In all the prints, the topographical features were distinguishable; but in one obtained at 650 metres above Stamford Hill, in the northern part of London, the features were particularly well defined; in fact, with the aid of a microscope, the smallest objects could be easily recognized. Experiments of this nature are now being made at the school of ballooning at Chatham.

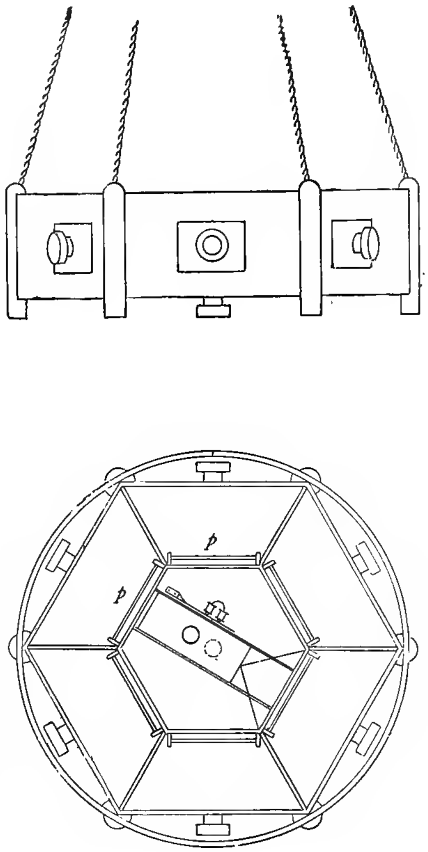

FIG. 54.

57. *Special Apparatus for Balloon Photography.*—In the instances given, the aeronaut occupied the car and manipulated his camera in the usual way; but, in 1884, M. Triboulet devised another method of working. He constructed a hexagonal willow basket to contain the photographic apparatus, and suspended it beneath the car of a captive balloon. The latter was unaccompanied by an aeronaut,—electric communication with the earth, by means of a light cable, serving to make the exposures. As shown in Fig. 54, the interior of the basket was subdivided into seven dark chambers; six of the objectives were disposed horizontally to obtain a tour of the horizon, while the seventh projected

through the base of the basket and gave the view beneath. Sensitive dry plates about 8×10 inches in dimension were used, the plate-holders occupying the positions *p*; and the images on the plates overlapped 0.4 of an inch to facilitate joining the prints. The instantaneous shutter, drop-pattern, was arranged as shown in Fig. 55; the drop *a*, held in the grooved strips *b*, was retained in position by the stop *c* attached to a metal spring *d*; on closing the circuit the electro-magnet *e* withdrew the stop, and the drop was quickly closed by means of the rubber bands *f*. The photographs obtained in this instance were fairly good.

At the close of 1884, M. Cassé made use of a very small captive balloon; and, to avoid the weight due to the use of an electric cable, substituted slow-match, which being of a length corresponding to the period of ascent, released the stop (*c*, Fig. 55) at the proper elevation. Clock-work has also been employed for this purpose. Experi-

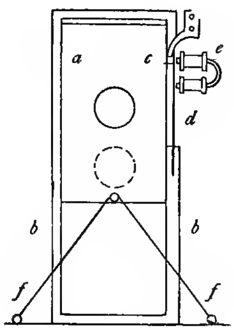

FIG. 55.

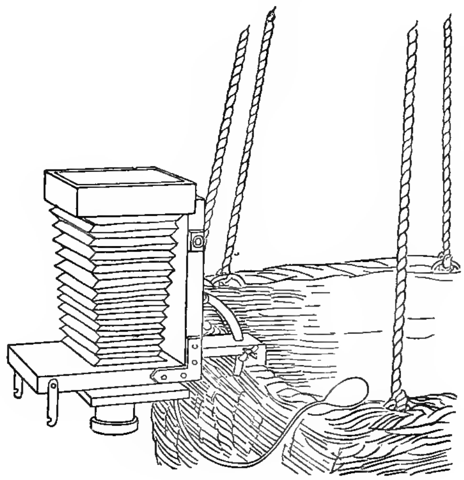
FIG. 56.

ments of this nature and attended with similar results were made at Chatham during the same year.

58. *Notably Successful Experiments.*—A notable instance is afforded in the experience of MM. Tissandier and Ducom at Paris in 1885. The ascent was made at 1.40 P.M., in a partially cloudy atmosphere, and with a wind-velocity of about 12 miles per hour. The photographic apparatus consisted of a 5×8-inch camera, Mackenstein tourist pattern, attached to the car as shown in Fig. 56; and a Français rapid rectilinear objective No. 4, having a 22-inch focus and an opening of 1.4 inches, stopped to 1 inch. The drop-shutter used gave an exposure of $\frac{1}{50}$ of a second, and the gelatino-bromide plates were specially manufactured for the purpose. Exposures were made at altitudes varying from 600 to 1100 metres; several were very successful, the best appearing to be that at 600 metres above the isle of Saint-Louis, and in which, with the aid of a microscope, the coils of rope contained in the passing boats are plainly visible—a tracing from the photograph, in the author's possession, is given in Fig. 57. The most sharply-defined views were obtained when the sun's rays were so oblique that slight shadows were cast. The motion of translation did not affect the sharpness, but it was found best to spring the shutter near the beginning or end of an oscillation.

In July of the same year, M. Pinard, of Nantes, obtained good 7×9 negatives from exposures made at altitudes varying from 400 to 1700 metres. He used a 10-inch focus Steinheil antiplanat, with a stop of $\frac{1}{15}$, and the drop-shutter gave an exposure of $\frac{1}{80}$ of a second.

The latest and best results appear to be from the experiments of Captains C. and P. Renard and M. Georget in 1885, and of MM. Tissandier and P. Nadar in 1886. Of the many good photographs made by the former party, that one obtained at 10.17 A.M., at an altitude of 720 metres, deserves especial mention for fineness of detail. The latter party of aeronauts made an ascent lasting 6 hours, and obtained 30 photographs, including some from an altitude of 1200 metres; various dispositions of the camera were

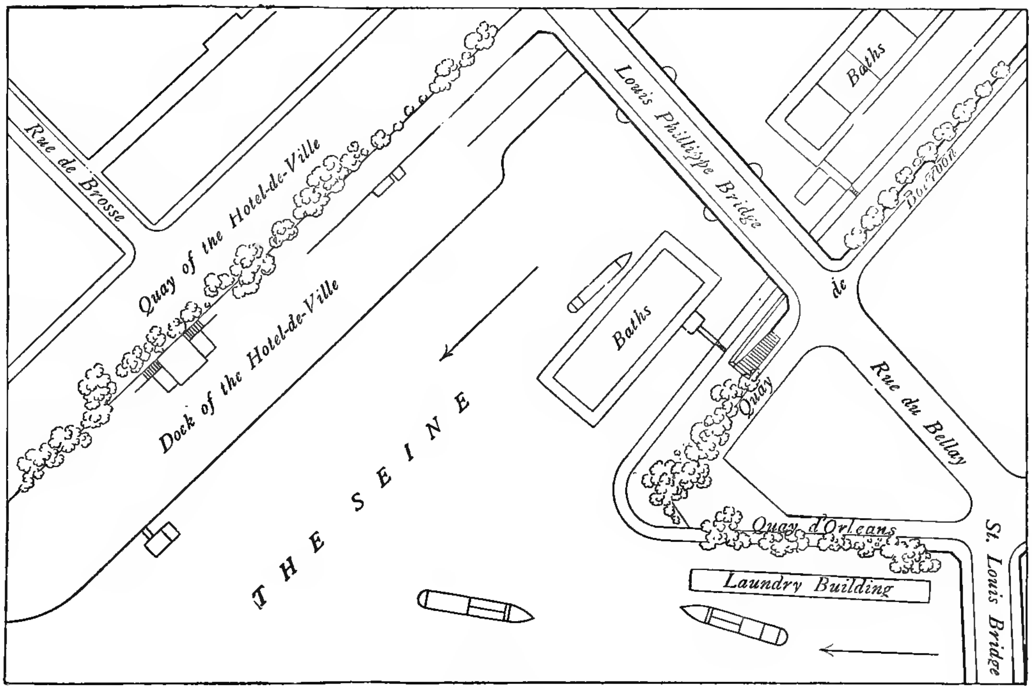

FIG. 57.

made in order to obtain both plan and oblique views. The time of exposure was $\frac{1}{250}$ of a second.

59. *Photographic Outfit and Method of Working.*—The following is a brief description of Mr. Shadbolt's preparations for balloon photography: "My list of requisites comprises a $5 \times 7\frac{1}{2}$-inch camera, a good supply of double plate-holders, lenses, shutters, etc., an aneroid barometer with altitude-scale registering up to 15,000 feet, a pocket-compass and maps of the country over which I am to travel, and a copy of Murray's threepenny time-tables, small edition, which comes in handily on landing. If circumstances permit, I prefer to fix my apparatus before starting;—the case containing the slides, etc., being attached to the side-ropes of the car by means of a strap, so as to be close at hand, and the camera fixed in its place on the edge of the basket by means of any simple device. . . . The barometer I fasten to the rigging close by the camera, so as to enable me to record the altitude as each exposure is made."

60. *Use of Small Balloons, Captive and Free.*—In 1881, Capt. Elesdale, R.E., proposed to use a small balloon, either captive or free, having sufficient lifting power to carry a very light camera to any desired height; the exposure to be made at the proper time either by electric apparatus controlled from the ground, or, automatically, by clock-work attachment. In his subsequent experiments, various devices were employed to ensure a proper direction of the optic axis; for plan views, the axis was kept vertical by attaching the camera, pointing downward, to a rectangular frame, suspended horizontally from a ring beneath the balloon by means of four cords or steel chains of equal length; for inclined views, the optic axis was to be pointed in any desired direction by attaching the camera to one end of a bamboo rod, the retaining or ground cord being secured to the other end, while the rod was suspended at the required angle by two cords of different lengths; a light sail, formed by filling in the triangle of the rod and cords with silk, was suggested as a means for keeping the camera steady in the direction of the wind. In case of no wind, a multiple camera similar to that used by M. Triboulet (see par. 57), was to be employed.

For military purposes, as in the case of an investment, the besieger could resort to either one of the two following processes for obtaining comprehensive views of the enemy's position:

a. A line of connected balloons is to be floated across the position, and the views are to be taken in transit as follows: Having selected a suitable point to windward, its location being accurately ascertained by the preliminary use of one or more pilot-balloons, balloon No. 1 with camera attached is sent up, its retaining-cord of silk, or best hemp, being paid out freely from a windlass running on friction-rollers, so as to offer as slight a resistance as possible. No. 1 having reached its equilibrium level, say 2000 feet, No. 2 is instantly toggled on and sent up; then No. 3, and so on throughout the series of five or more; the interval, or section of cord between balloons, evidently depending upon the lifting power. No check of ascent is to be permitted, or the series will tend to pivot around the starting-point and come to the ground. The automatic apparatus is set at the proper time for making an exposure, from observation of the rate of travel of the pilot-balloons; or, for the later balloons of the series, from information communicated by signals from an assistant, stationed in a direction perpendicular to the path, and who would observe the leading balloons.

The system is brought to the ground beyond the enemy's position by attaching a very light grapnel, with a suspension cord 50 to 100 feet in length, to the last balloon; and by cutting a small hole near the crown of the latter to permit the gradual escape of its gas, which will begin to be effective when the balloon has reached its equilibrium level.

b. In the other process, each balloon is to be sent up independently, the escape of gas being so provided for, as above, that the balloon shall descend at a suitable distance and be held by its grapnel.

In a special case, as in the close investment of a fortress when it is necessary to ascertain if an inner line of defence is being constructed by the besieged, two methods are prescribed, the choice depending upon the direction of the wind. First, when the

wind is favorable and blowing towards the enemy: the small balloon is inflated in the advanced trench, say at 200 yards from the work; it is sent up, with camera attached to a rod, as above described; the view is taken at, say, 80 yards from the work, when, by the release of a weight suspended from the balloon by a cord, which is automatically parted by the burning of a time-fuze, the balloon rapidly ascends out of reach of the enemy's bullets; the windlass is then quickly carried to the rear trenches, the cord being paid out freely, and the balloon is hauled down at a safe distance. Provided the camera is not hit, a few bullets through the envelope do no harm. In the second case, when the wind is from the opposite direction: a solid shot, to which a short length of chain connected with a fine hempen line is attached, is fired with the proper powder-charge to a point near the crest of the glacis; the balloon, fastened to the line and also to its retaining cord, is then sent up; the line is burned through at the proper time by a time-fuze, the balloon rises rapidly and is hauled down as before.

To ensure steadiness of ascent and to prevent oscillation of the captive balloons, Capt. Elesdale prescribes that "all vertical strain except that due to the dead weight of the cord itself should be removed; and all horizontal strain should be avoided if possible, and when this is not possible it should be changed into a small, steady and uniform retarding force, instead of an unyielding pull, until the picture is taken." In case of the balloon rising to still air above a wind-current, to keep it in position "the drifting lower portion of cord must be fed with more cord from the ground as fast as it will run out."

As a result of his experiments up to August, 1883, Capt. Elesdale remarks "that with a proper and thoroughly worked out apparatus, constructed by the aid of opticians and mathematical-instrument makers, so as to admit of instrumental accuracy in all the processes, and for pictures taken on ordinary ground (not representing any violent slopes or extreme differences of level) we may expect to attain by balloon photography more accurate plans than are usually obtainable by ordinary surveying."

61. *Observations on Balloon Photographic Surveying.*—The facts given in paragraphs 55 to 58 show that good photographs, giving either vertical, oblique or panoramic views of a country, may be obtained from balloons; and the first question now presented appears to be whether, aside from their value as pictorial representations, they may be used as data for the construction of exact or true maps.

I. *With Captive Balloons.*—Taking first the case of a single view: *When a balloon in mid-air is stationary*, as in the case of a captive balloon in still weather, a panoramic view obtained corresponds to cases described in the preceding sections; with a difference in its favor, however, that the point of observation is exceptionally commanding. The vertical or plan view—that obtained by pointing vertically through the base of the car—affords under favorable illumination a perfect means for the measurement of horizontal angles; the middle point of the view being the radial or angular point. A vertical view of a flat tract would be a most perfect and detailed map or plan of itself, and could be enlarged or reduced as desired to conform to any scale,—the plans of buildings, which, by their positions in the outer part of the view, would present one or more faces, being given by the bases; but in the case of a mountainous or hilly tract, neither the eleva-

tions nor horizontal distance would, as a rule, be truly represented. Thus, as shown in Fig. 58: at the altitude PB, the peak D is projected by a visual ray in D' instead of D'', representing an error of $D''D'$ in its horizontal distance from P. Both the distance PD'' and the elevation $D''D$ may however be readily determined as follows: On the print, measure the angle @, which is given by its tangent, PD',—PB being measured by the aneroid; from the station P measure the angle of elevation @′; plot the triangle PDB, in accordance with the scale of the map; then $D''D$ and PD'', measured by this scale, are respectively the elevation and horizontal distance required. For oblique views, the plotting would be more complex—the measured angles requiring the correction due to the angular displacement of the optic axis from a vertical. It has been suggested that compensation for obliquity of the plane of the picture, due to either uniformly sloping ground, the optic axis being vertical; or to an oblique position of the axis, in the case of flat country; may be effected, as in copying by photography, by a simple adjustment of the original photograph, or of the sensitive plate, in a secondary photographic process.

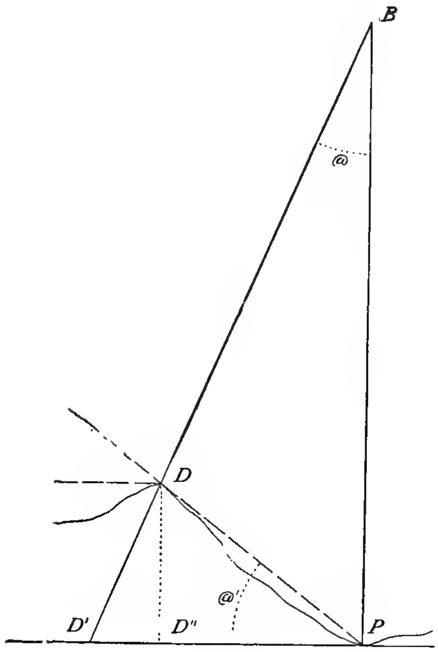

FIG. 58

When the captive balloon is not stationary, and even when oscillating under a strong wind, it is shown, from experiments made at Berlin in 1885, that the car itself can be maintained with its base horizontal. The cords of the net, instead of converging in the usual manner to a ring beneath, were attached at intervals to a horizontal bar. For the balloon used,—a sphere of 50,000 cu. ft. capacity, filled with hydrogen, and carrying eight persons,—the bar was 2 inches in diameter and 33 feet in length, and the car was suspended from its middle point; two light cables 0.4 inch in diameter were fastened one to each extremity of the bar, and were joined 65 feet beneath it to the main cable. Suppose the balloon to be moved out of the vertical of the station; then, if the sensitive plate is horizontal, the view itself will show the intersection of the optic axis with the earth; this point might also be fixed by bearings of known points taken from the car, or by transit measurements from the earth,—the instant of exposure in the latter case being communicated by signal.

If a series of views are thus taken above known points of an extensive tract, they may be used in plotting as so many protractors, by fastening their centres with needle-points to the plotted stations; then, by orienting them and conforming to the plane-table method of intersections, the required points are readily located. A scale for any single view is easily constructed from the ratio of any represented distance to the corresponding actual distance. For the general plot, since the method of intersections is independent of the diameters of the views, differences of altitude would not affect the construction of a plan, it being only necessary to fix the stations to scale.

From an altitude of 2000 feet excellent photographs have been obtained; and each

of these, taken with a Hermagis 90° lens, would represent an area about $\frac{3}{4}$ of a mile square; while from a 3250-ft. altitude, at which good results are noted, the area would be about $1\frac{1}{4}$ miles square.

II. *With Free Balloons.*—But few experiments in photographic surveying with free balloons have up to the present date been recorded; but the proposition seems by no means infeasible, since the dirigibility of balloons has become practicable. In the experiments of Captains Templar, Lee and Elesdale, at Woolwich in 1879, the differences in direction of the air-currents at different heights were utilized to travel in any desired direction; a small pilot-balloon of about 200 cu. ft. capacity being made to ascend or descend a distance of 2000 feet from the car, to show the directions of the air-currents. At Meudon, in 1884, Capt. Renard, with a balloon propelled by means of an electric motor, the screw being at the bow, and steered with a rudder-sail, travelled at will in a 9-mile wind, at the rate of 14 miles an hour, returning after a trip of 47 minutes to the point of departure. It is evident that, in either of these cases, vertical views taken at proper intervals would have furnished a map of the entire country passed over. More recently, Captains Renard and Krebs have perfected an electric motor which ensures a continuous voyage of four or five hours' duration.

For the purpose of measuring altitudes with precision in balloon surveying, M. Casella has recently constructed a very sensitive aneroid barometer which indicates differences in height of one foot.

With very sensitive plates and rapid shutters, the photographic operations are of easy performance, and photographs are obtained that lack nothing in clearness and accurate representation. Much assistance is afforded to military art in the rapidity and faithfulness with which the enemy's defences and positions may be depicted; and to the geographer the means are supplied for obtaining descriptions of isolated tracts and of those inaccessible by ordinary means. Panoramic and plan views well combined give results of great interest, and present to the aeronaut and photographer new and important applications of their arts.

SECTION VII.

VARIOUS APPLICATIONS OF PHOTOGRAPHIC SURVEYING, AND SOME OF ITS ADVANTAGES.

62. *General Considerations.*—It has been shown in the preceding pages that with the camera as a surveying instrument the field-work may be performed with great rapidity, and with an economy of men and material exceeding that due to other means; and that, in the plotting, the plan results from an application of the very simple method of intersections; while the representation of heights and surface-forms is accomplished either mechanically, or by the use of tabular values which may be easily and rapidly applied. As to the contouring, it is apparent that in some cases, owing to the surface-covering of trees and the interposition of projecting spurs or salients, the lesser inequalities are not given in the prints; but this deficiency can be supplied, as in other methods, by field-sketching; and, in respect to this part of the work, it may be said of this method, as of ordinary topographical surveying, that the production of a complete map requires a true appreciation of forms of ground. With carefully-constructed instruments, and most of the standard cameras and rectilinear lenses now made are suitable, the results exceed in precision those ordinarily obtained with either compass or plane-table; and as to thoroughness of detailed description, there is of course nothing to exceed a photographic representation.

63. *To Farm-surveys and Engineering Purposes.*—For farm-surveys, fields, and small tracts in general, a few exposures—in many cases three will suffice—from well-selected points furnish the data for a complete map.

For engineering purposes, aside from its adaptation to the topographical survey of projected routes of railroads, canals, and other subjects which have already been referred to, this means is especially useful for conveying information as to the condition of important constructions. Photographs obtained at different stages in the progress of the work in hand afford descriptions which, for thoroughness, written communications are inadequate to give; these faithful records, representing the site, foundations, intermediate conditions of the structure; with date, number of men at work, state of the weather, etc., noted on the back of each print, are very valuable for future reference.

64. *To Geographical and Archæological Descriptions.*—As an aid to the geographer this means is of great value. The difficulties due to optical illusion which, in ordinary topographical sketching, mountainous or hilly tracts present, are obviated; from the peaks, panoramic views are comprehensive and far-reaching; and exposures from the less elevated points furnish details of the deeper valleys, and of those tracts which from the peaks are either shut out or obscure. The choice of illumination, properly exercised, gives a definition to surface-lines and points, that actually appears sharper in a print than in nature;

therefore, as compared with ordinary observation, a more accurate map-delineation results. Both geological and botanical information are included in the print,—the rock-structure, peculiar formations, deposits, the forest and individual growths, and much else that assists to a thorough knowledge of the country.

Profile views of a range of mountains or hills, taken either from peaks or favorable points of a valley route, are excellent data for plotting. The directions of stations from each other are ascertained by compass-bearings; while the aneroid would prove of valuable assistance in the levelling, and the odometer would measure the distances between stations of the valley route. Coast-lines also may be accurately described from views taken off shore. For the representation of inaccessible objects, tracts, summits, declivities, morasses, or craters, the method is unrivalled.

To the archæologist its use is of inestimable value; intricate lines of figure of buildings, monuments, or earth constructions, are faithfully produced, and their measurement is thus made easy of accomplishment. The photographic survey of Persepolis and of the Mosque of Mesdjid-a-djunia, by Dr. Stolze, are recent instances of its successful application.

As addenda to plotted maps, the photographs, for minute information, will often serve the same purpose as actual inspection.

65. *To Military Purposes.*—The rapidity with which ground may be represented offers special advantages to the military service. As an instance of rapid work: In 1874, M. Javary made in one day, in the valley of l'Arly, a photographic reconnaissance extending 14 miles, and embracing the features within a distance of from one to two miles on either side of the route followed. This work was performed with two cameras of the ordinary type, a compass and a stadia. The two last instruments were kept on the route, while a photographer, with stadia-rod and camera, marched on each side. At a given signal, the distance to either photographic station was measured by the stadia, and its bearing taken; the photographer took the bearings necessary to orient his views; and means for checking the orientation were supplied by bearings, taken from the stadia-stations, of prominent points that would appear in the views.

On another occasion, M. Javary made, in six hours, a photographic survey of the ground included in a zone three fourths of a mile in width, in front of a fortified place; and, after 8 hours expended in the plotting, presented the commanding officer of the attacking force with an *exact and complete map, including the levelling; and this in rainy weather and with wet plates.* He states that, with four operators, the exact survey of any fortified place can be made and plotted within 24 hours.

As an instance of its value in defensive operations, views of the surrounding country may be taken from the different salients or other commanding points of a work; the distances to the enemy's batteries, etc., ascertained from the plotting, can then be noted on the representations of the objects, and the prints distributed to the chiefs of pieces, who are thus enabled in an instant to get the range of any contained point.

Aside from the merit of this method as a means of military surveying, the representation by photographs of all the details possesses a special advantage in camp or field; it may happen that a knowledge of some feature of ground, which in ordinary

topographical sketching might be omitted, would prove of great value; again, the naturalness of a photographic representation might convey to some the information not afforded them by a topographical map.

Since balloon photography claims such an important part in warfare; the element of danger to the aeronaut, from the enemy's fire, is of considerable moment. During the siege of Paris, the Germans made use of a large rifle so mounted, and furnished with stock and butt, that it could be fired from the shoulder; this was transported by wagon to points over which the French balloons chanced to pass, and some of the aeronauts testified to hearing the bullets whiz by them when at altitudes of from 800 to 1000 yards. In November, 1870, one balloon, "La Daguerre," lost so much gas from perforation by the balls from the ordinary infantry rifle, that it had to descend and was captured by the Prussians. From experiments subsequently made by the French war department it was found that, at an altitude of 1300 feet, a balloon 13 feet in diameter was unharmed by the best sharpshooters with a chassepot rifle; but from the testimony above given, their failure in attaining it must have been due to ignorance of the true form of the trajectory when the line of fire is inclined to the horizon. It is found, theoretically, that with a chassepot rifle, model of 1874, the extreme range in firing upward, at angles between 80° and 90° with the horizon, is nearly 2100 yards, while the effective range as against an ordinary balloon is about 800 yards; for angles between 60° and 70°, the effective range is increased to about 950 yards, and between 40° and 50° to about 1000 yards. (For an elaborate discussion of this subject, see "Tir Contre les Ballons," by Dufaux, 1886.)

The "Jahresberichte" enumerates the following conditions to be fulfilled, in order that balloons may be generally adaptable to military service:

I. To be readily transportable, either inflated or empty.

II. That the envelopes shall be resisting and impermeable to the contained gas, in order that they may lose as little as possible of their ascensional force.

III. The means to be supplied for filling them rapidly, in any place whatever, and of replacing the gas lost.

IV. For free balloons: power to move in any direction, of landing promptly and with security, also of rising promptly.

V. For captive balloons: means for preventing rotation about a vertical axis, and for causing them to rise in good condition notwithstanding the wind.

Experiments very lately made in France and England have been successful as to the first three conditions; as may be observed in the preceding pages (Section VI.), the fourth and fifth are in a fair way of fulfillment; and it certainly seems, after having within a comparatively short period surmounted so many obstacles, that the efforts made to perfect this valuable aid to scientific investigation, for civil as well as military purposes, will soon meet with a favorable termination.

66. *Some of the Advantages Derived from its Use.*—In photographic surveying, an entire tour of the horizon, or any desired part thereof, is obtained in a few minutes by a series of very simple operations, involving no multiplied or fatiguing observations; no drawings, sketches, or lines of direction difficult to trace in the field; no delicate pointings or minute readings, and no prolonged computations. There is no fear of having forgotten, or omitted, some important point; because every visible detail is represented, and, when

negatives are used in plotting, with a precision that is rarely exceeded; there is also no occasion, as in other methods, for rejecting erroneous or doubtful observations.

The office-work presents no difficulties; the constructions are simple and rational; and errors of destination, pointing or orientation, are made impossible by the numerous verifications which serve at each step to check results already attained. All the work done in the field is of value, and there are no regrets for not having made all useful observations at any station.

The map finished, the photographs, as addenda, present as already stated a view as perfect and comprehensive as if the observer had personally traversed and inspected the tract or region represented.

The only inconvenience that seems to present itself, is that of acquiring a certain degree of skill in the chemical manipulations; but this part of the work is now reduced to such simplicity that but little practice is necessary for the purpose; besides, in surveys of considerable extent, a professional photographer would usually be retained.

Finally, in the prosecution of a survey, the stations may often be so selected that in the views artistic effect and necessary data are joined, and the resulting photographs would thus be made as interesting in the former respect as they are useful in the latter.

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